AD NUMBER

AD804522

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution: Further dissemination only as directed by Federal Aviation Agency, Washington, DC, Sep 1966 or higher DoD authority.

AUTHORITY

FAA ltr, 10 Oct 1972

Pratt & Whitney Aircraft
FLORIDA RESEARCH AND DEVELOPMENT CENTER

U
A

NOTICES

When Government drawings, specifications, o other data are used for any purpose other than in connection w · a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

All distribution of this document is controlled. This document may be further distributed by any holder <u>only with specific prior approval of</u>:

Director of Supersonic Transport Development
Federal Aviation Agency
Washington, D. C. 20553

The distribution of this document is limited because it contains technology identifiable with items excluded from export by the Department of State (U. S. Export Control Act of 1949 as amended).

PWA FP 66-100

(11) SEP[redacted]

(12) 378p.

(6) ENGINE PROPOSAL

FOR PHASE III OF THE

SUPERSONIC TRANSPORT DEVELOPMENT PROGRAM.

VOLUME IV.

SYSTEM INTEGRATION.

(15) FA-SS-66-8

(14) PWA-FP-66-100-Vol-4

(COMPETITIVE DATA)

PREPARED FOR

FEDERAL AVIATION AGENCY

OFFICE OF SUPERSONIC TRANSPORT DEVELOPMENT

WASHINGTON, D. C.

Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION

FLORIDA RESEARCH AND DEVELOPMENT CENTER

UA®

№ 13

(401 355)

Printed in the United States of America

CONTENTS

15

CONTENTS (Continued)

CONTENTS (Continued)

REPORT A
OPERATIONS

As stated in the RFP, Report A, Operations, is applicable only to the airframe manufacturer.

REPORT B
SONIC BOOM AND NOISE

As stated in the RFP, Report B, Sonic Boom and Noise, is applicable only to the airframe manufacturer.

REPORT C
ENGINE SAFETY PLAN

SECTION I
OBJECTIVE AND SUMMARY

A. OBJECTIVE

The objective of the JTF17 Engine Safety Plan is to assure that no other consideration will be placed higher than the consideration of safety in the supersonic transport engine.

B. SUMMARY

The Engine Safety Plan presents Pratt & Whitney Aircraft's approach to assuring engine safety. Included is an Operational Safety Analysis of the engine as installed. The Engine Safety Plan establishes safety considerations during engine design and development to assure maximum safety during airframe/engine integration and operation of the Supersonic Transport.

SECTION II
SAFETY MANAGEMENT, ORGANIZATION, AND POLICIES

A. SAFETY MANAGEMENT

The development of the JTF17 engine is conducted under a program management system. Under this system, overall responsibility for the design, development, production, and service operation of the engine is placed in the hands of the Program Manager. The Program Manager has complete control of the engine program and authority to take the necessary action to achieve program objectives including safety.

The JTF17 Safety Engineer reports through the Product Assurance Manager, to the JTF17 Program Manager.

The Product Assurance organization will provide positive management control of the related disciplines of safety, reliability, maintainability, quality assurance, human engineering, value engineering and standardization. It is an organization well suited to coordinating the airframe, engine, airlines and Federal Aviation Agency requirements in these areas. The assignment of a single individual responsible for each discipline will improve communications between Pratt & Whitney Aircraft and these organizations. The Product Assurance organization is described and illustrated in Volume V, Section IX.

The JTF17 Safety Engineer will be specifically responsible for implementing and directing the Engine Safety Plan.

1. Program Safety Engineer

The JTF17 Safety Engineer's primary responsibility will be to assure maximum safety throughout the design, development, production, and service phases of the Program. The JTF17 Safety Engineer will have the following safety-oriented responsibilities and functions:

1. Review and approve design layouts

2. Coordination of engine safety requirements and activities with other organizational elements within Pratt & Whitney Aircraft, the airframe contractor, and the Government

3. Direction of support groups in the performance of safety analyses, documentation, and reporting as required.

2. Support Group Relationships to Program Safety Engineer

The JTF17 Safety Engineer gives direction to specific support groups in all phases of the engine program.

Formal communication of safety work to be performed, work assignments, and schedules will be provided to these groups by the JTF17 Safety Engineer through Engineering Order Supplements. (The EOS is a standard Pratt & Whitney Aircraft form issued by Engineering which defines

and authorizes work and cost to be charged to the Engineering Order.) The JTF17 Safety Engineer will maintain a close working relationship with these groups to provide guidance to assure that engine safety objectives and requirements are met. He will report safety progress and findings to the Manager, Product Assurance and other program personnel, as shown in figure 1.

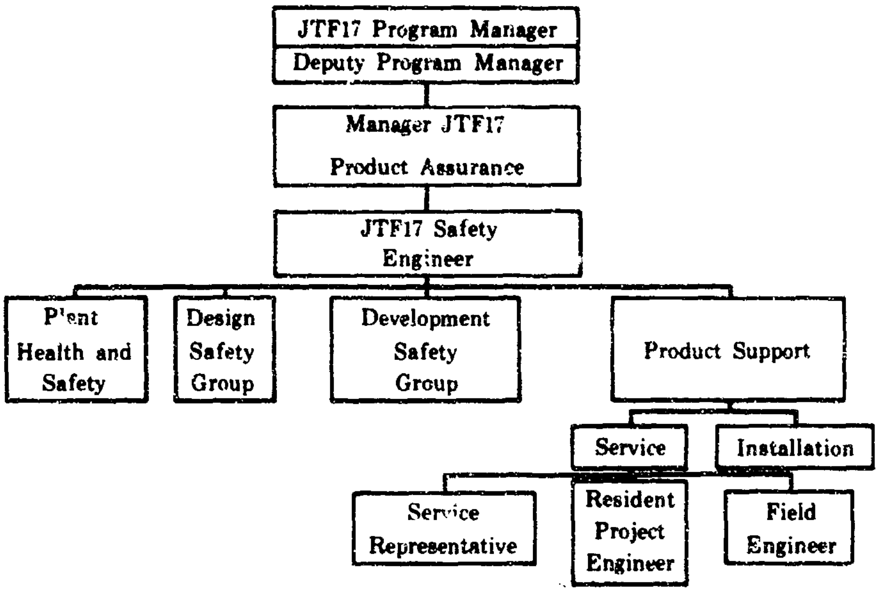


Figure 1. Safety Organization Chart FD 16514 CII

B. SUPPORTING GROUPS

1. Engineering Support Groups

The Design Safety Group and the Development Safety Group are the two Engineering groups that support the JTF17 Safety Engineer in providing safety analyses throughout the program. As directed by the JTF17 Safety Engineer, these groups have the following safety responsibilities throughout the JTF17 Development Program:

1. The Design Safety Group will provide safety analyses, documentation, and reporting.

2. The Development Safety Group will provide assistance and safety analyses during development. This group will provide rapid feedback of data pertaining to any hazards which might be experienced during development by means of Development Problem Reports and Failure Malfunction Reports. Safety Engineering will initiate the necessary corrective action.

2. Product Support Group

The Service and Installation Engineering Groups will support Safety Engineering during the design and development of the JTF17 engine.

The safety-oriented functions of these support groups throughout the JTF17 engine program include the following:

1. Provide data pertaining to operational experience on current engines for feedback into the design and development of the JTF17 engine.

2. Assist the JTF17 Safety Engineer in resolving any safety problems that arise during engine-airframe integration or operation.

3. Provide input to establish procedures and instructions for safe installation, operation, maintenance, and overhaul. These procedures and instructions will be published by the Technical Publications Group in the form of Service Manuals, Service Bulletins, Installation Handbooks, and Operating Instructions.

During the ground and flight test phases of the JTF17 engine program, problems affecting safety will be immediately acted on by the Service Representative in coordination with a resident Project Engineering representative and Field Engineer and reported by telephone or teletype to the Product Support Manager and the JTF17 Safety Engineer. The initial report will be followed by a formal Service Representative's Report.

Generally if the problem is concerned with a failure, the failed part will be returned to Pratt & Whitney Aircraft for visual inspection, metallurgical or chemical analysis or dimensional inspection. As soon as the cause of failure is determined, an Engineering Change in Design will be processed and retrofit changes made if required.

For those instances requiring immediate action, changes in procedure or part time limitations will be disseminated in the form of Field Notes or Service Bulletins to ensure safety until the final design can be incorporated.

3. Plant Health and Safety Group

A staff of safety specialists is maintained within P&WA to monitor and control any hazardous situations that arise during the manufacture, assembly and test of the engine. Internal Bulletins are issued by this group to provide precautionary instructions for such things as toxic nature of machining copper beryllium parts, use of explosive rivets, load limits of engine hoists, radioactive inspection procedures and fire control in areas of concentrations of volatile mixtures.

If it is expected that similar situations will exist in the overhaul shop or in the airframe installation, these bulletins are incorporated as required into the applicable Technical Manuals for use by the airline, airframe manufacturer and/or the overhaul shop.

SECTION III
SAFETY REQUIREMENTS

Safety requirements (design-safe, fail-safe) will be met in the design phase, verified in the development phase, and maintained in any subsequent design changes throughout the program. The requirements, as listed in the following paragraphs, cover flight safety, ground safety, and personnel safety. Design features that are incorporated to satisfy these requirements are presented in Section IV.

A. FLIGHT SAFETY REQUIREMENTS

1. Ice and Bird Ingestion Capability

In accordance with weight and size criteria established by FAA regulations, the ingestion of foreign objects, such as birds and hail, shall not jeopardize continued safe-operation of the engine at thrust levels required for safe operation of the aircraft.

2. Rotating Parts

The compressor and turbine system shall be free of destructive vibration at all engine speeds and thrusts (including steady-state and transient conditions) throughout the complete operating range of the engine. Disk and blade design shall provide for safe operation within the specified operating limits.

3. Blade Containment

The design of the engine cases, including the fan case, shall provide for containment of rotor blades in the event of rotor blade failure.

4. Bleed Air Contamination

The air at the bleed ports shall contain not more than the amounts of engine-generated noxious, toxic, or irritating substances specified in the JTF17A-21 Engine Model Specification No. 2698A, paragraph 27.2.1 and the JTF17A-21 Engine Model Specification No. 2710, paragraph 27.2.1.

5. Fuel Contamination

The engine shall function satisfactorily when using fuel contaminated to the extent specified in the JTF17A-21 Engine Model Specification No. 2698A, paragraph 15.4.1 and the JTF17A-21 Engine Model Specification No. 2710, paragraph 15.4.1.

6. Electrical Power

In the event of loss of externally supplied electrical power, the engine shall continue to operate safely at all engine speeds at or above idle and throughout the complete thrust range, provided that exhaust gas temperature limits are observed. Loss of electrical power would result in the inability to relight the duct heater and gas-generator and to manually electrically adjust the main fuel control.

7. Emergency Shutdown of Engine

The capability of a safe engine shutdown in the event of engine failure shall be provided to preclude further escalation of damage.

8. Fuel Pump Minimum Inlet Pressure Requirements

The fuel pump shall be designed to deliver the required quantity of fuel under emergency conditions of minimum inlet pressure such as loss of the main fuel boost pump impeller or failure of the aircraft boost pumps.

9. Anti-Icing Provisions

Engine air bleed will be provided for airframe use, as necessary, to prevent the formation of ice at the inlet duct.

10. Fire Considerations

All possible consideration shall be given to the prevention of any fire hazard caused by the engine in the airframe nacelle.

a. Fire Analysis

An analysis shall be made of the installed engine to determine the possibility of spontaneous ignition of any combustible mixture in the engine compartment as well as ignition from electrical sources or engine case burnthroughs. The use of magnesium housings shall be avoided.

b. Ignition

All electrical components (except igniter plug electrodes) shall be ignition-proof in order not to ignite any combustible mixture surrounding the equipment.

c. Fluid Leakage

There shall be no leakage from any part of the engine except at the drains provided for this purpose. The quantity of leakage from all fuel drains provided shall not exceed the limits shown in the JTF17 Engine Model Specification No. 2698A, Paragraph 15.5 and Model Specification No. 2710, Paragraph 15.5.

d. Combustible Fluid Drains

Provisions shall be made for automatically clearing the combustion area of combustible fluids after each false start and for preventing combustible fluids from entering the combustion areas after shutdown. Provisions shall also be made for clearing all vent areas and other pockets or compartments where combustible fluids may collect during or subsequent to operation of the engine.

e. Fire-Shield Provisions

Provisions shall be incorporated in the engine cases for mounting a fire-shield bulkhead to isolate the hot section of the engine.

B. GROUND SAFETY REQUIREMENTS

Any Safety requirements such as jet wake characteristics for ground operation and checkout shall be specified in service maintenance manuals and operating instructions.

C. PERSONNEL SAFETY REQUIREMENTS

Personnel safety requirements such as radioactive hazards shall be emphasized throughout the program. For those hazardous tasks that cannot be eliminated, written procedures shall be established for accomplishment of the tasks that will reduce to a minimum the danger to personnel.

D. FAILURE ESCALATION CONSIDERATIONS

In consideration of the flight, ground and personnel safety requirements just discussed, Failure Modes and Effect Analyses shall be conducted as described in Section V. All failure possibilities shall be eliminated or reduced from the catastrophic failure mode* to a fail-safe condition, and further escalation of damage shall be prevented.

E. CONSIDERATIONS FOR WHEELS-UP LANDING

All large-volume combustible fluid-carrying components shall be located away from the bottom of the engine to minimize fire hazards during a wheels-up landing.

*See Appendix for a discussion of hazard classification definitions.

SECTION IV
DESIGN APPROACHES AND CRITERIA

The following design approaches and criteria have been incorporated into the design of the JTF17 engine to meet the established safety requirements presented in Section III of this report and will be the criteria throughout Phase III and beyond. These approaches and criteria have evolved as a result of P&WA's extensive experience with commercial aircraft and high-Mach-number high-altitude jet engines.

A. ICE AND BIRD INGESTION

Engine parts that define the primary gas path are provided with adequate strength to endure the impulse loads imparted by ingested foreign objects. The use of two shrouds on the fan blades greatly increase tolerance to foreign object ingestion such as seagull-size birds and large hailstones by limiting deflection at impact.

Verification of the ingestion capability of the design will be accomplished by actual tests as listed in Volume III, Report E.

B. ROTATING PARTS

The design of disk and blades provides for safe operation within the specified limits through application of the following design criteria.

1. Disk Burst Margin

The term "burst margin" refers to the ratio of two speeds: the lowest speed at which the disk might be expected to burst (based on minimum strength properties of the material), divided by the highest anticipated operating speed. The latter speed is the maximum nominal speed increased by 2% for normal tolerances experienced in production and an additional 3% for normal deterioration experienced in service usage.

Burst margin for compressor disks is 20% and for turbine disks is 30%.

2. Shaft Failures

A fail-safe design is provided to prevent turbine overspeed in the event of a shaft failure by the selection of axial clearances (between the rotating turbine blades and the stationary turbine vanes) that cause the blades to contact the vanes prior to any part contacting the disk. This prevents any catastrophic failure that might be caused by engine disk failure.

The JTF17 engine has an added safety advantage of a very short compressor section (44 in.) and turbine section (14-1/2 in.), which results in only 58-1/2 inches of airframe length that must be considered in the placement of critical components to preclude their failure in the event of an engine disk failure.

3. Low Cycle Fatigue

Disk failures are minimized by strict adherence to published low-cycle-fatigue (LCF) limits. These limits are constantly reviewed and adjusted as a result of accelerated laboratory tests and field experience.

A major advantage to the JTF17 design in this respect is the use of integral spacers instead of individual bolted spacers, which move the stress concentration of the bolt hole to a low stressed portion of the disk. A detailed explanation of methods used to predict disk life can be found in Volume III, Report B, Section II.

4. Rotor Critical Speeds

The basic critical speeds of the engine compressor and turbine rotors are well out of the engine operating speed range.

The design of all rotor stages has been reviewed to ensure that no damaging harmonic resonances exist in the engine operating speed range.

C. BLADE CONTAINMENT

Each wall in a multilayer engine case in the plane of rotating blades contributes to blade containment. The fan portion of the engine takes advantage of the inner OD shroud plus the outer engine case. The high compressor and the turbine portions of the engine are surrounded by the two walls of the fan duct in addition to the compressor and turbine outer cases. Certain sections of the interior of the engine, where fuel lines exist, are further protected from penetration by local shielding.

The ability to contain blade failures is determined by an empirical "containment factor," which, basically, represents a measure of the relationship between the kinetic energy of the failed blade and the available energy absorption capability of the case.

Minimum material specifications and maximum load conditions are used to calculate the minimum case thickness, thereby providing a statistical factor of safety. (A more detailed description of blade containment can be found in Volume III, Report B, Section II.)

During the development phase of the JTF17 program, blade containment will be verified in tests outlined in Report E, Section I (Test Integration).

D. BLEED AIR CONTAMINATION

Incidents of oil-contaminated bleed air in previous commercial experience have been extremely rare. These incidents have been considered, with the result that concerted design effort has been generated to minimize the possibility of contamination by providing a duplicate seal system between the bearing compartments and airstream consisting of hydrostatic seals and multistage labyrinth seals having an overboard drain or other provisions for drainage between seal stages. Bleed air contamination limits are shown in the JTF17 Engine Model Specification No. 2698A, Paragraph 27.2.1 and Engine Model Specification No. 2710, Paragraph 27.2.1. Bleed air is extracted at the discharge of the high compressor at the leading edge of each of eight struts in the diffuser passage.

Nongaseous contaminants passing through the high compressor will be centrifugally forced to the outside diameter of the diffuser passage, where a step is provided in each strut to prevent this material from entering the bleed manifold. Thus, bleed air is not extracted at the outer wall where the maximum concentration of contaminants exists.

E. FUEL CONTAMINATION

Fuel filters are provided throughout the system to minimize the possibility of clogging the fuel nozzles, to minimize sticking of the close-tolerance servovalves in the control, and to protect the gear stage of the main pump and hydraulic pump. All components are tested to contamination limits shown in the JTF17 Engine Model Specification No. 2698A, Paragraph 15.4.1 and Engine Model Specification No. 2710, Paragraph 15.4.1

F. ELECTRICAL POWER

Loss of electrical power is not critical to engine operation. The engine is self-sustaining at or above idle without external electrical power. The only electrical equipment on the engine consists of the ignition system, the manually-controlled, electrically-operated, main fuel control trim motors, and position indicators for the duct nozzle, thrust reverser and aerodynamic brake.

G. EMERGENCY SHUTDOWN

The procedure for emergency shutdown of the JTF17 engine is the same as that for a normal engine shutdown. Main fuel supply valves in the airframe fuel line may be used in an emergency.

H. OPERATION OF MAIN FUEL PUMP AT MINIMUM INLET PRESSURE

The engine fuel pumps will operate under the emergency fuel supply conditions stated in the JTF17 Engine Model Specification No. 2698A, Paragraph 15.2 and Engine Model Specification No. 2710, Paragraph 15.2. The main engine fuel pump is designed to operate the engine up to 90% maximum thrust in the event of a Main Pump Centrifugal Boost Stage failure.

If a failure of the Airframe Boost Pumps is experienced, the engine fuel pumps will continue to pump the fuel at a pressure level and flow rate that satisfy the engine requirements as long as the inlet vapor-liquid ratio does not exceed the value shown in the Model Specification.

I. ANTI-ICING

The elimination of inlet guide vane structure for the JTF17 engine eliminates the need for engine inlet-guide-vane anti-icing.

If required, engine high pressure compressor bleed air will be provided for anti-icing airframe inlet as defined in the Engine Model Specification.

J. FIRE CONSIDERATIONS

All possible modes of failure that might result in the formation of combustible mixtures and subsequent ignition in the JTF17 engine nacelle are considered in the P&WA detailed fire analysis report (PWA FR-2005). This fire analysis report has been reviewed by the independent consulting firm of Lewis and Karlovitz, Combustion Associates of Pittsburgh, Pennsylvania Dr. Lewis and Mr. Karlovitz are recognized authorities in combustion. Their concurrence with the general conclusions of this analysis has been submitted to P&WA. A synopsis of this analysis is presented in the following paragraphs. All fireproofing considerations will comply with FAR 25 and 33.

1. Fire Analysis

All pertinent service experience involving engine case burnthrough has been and will continue to be reviewed to eliminate deficiencies in the JTF17 engine design. This analysis emphasizes the improbability of experiencing spontaneous ignition of any fuel-air mixture that might be present due to leakage in the engine compartment. It further shows how the possibility of engine case burnthroughs are minimized by "designing out" features that caused burnthroughs in past commercial engines. The possibilities of burnthrough to the engine nacelle are further minimized by the double wall of the duct heater, the large distance across the duct heater, and the high bypass ratios relative to subsonic jet engine.

2. Ignition System

Electrical equipment is hermetically sealed and is explosion-proof.

3. Fluid Leakage

The prevention of fluid leakage is achieved by emphasizing plumbing integrity. Pratt & Whitnev Aircraft's development experience in this field for high Mach number application is extensive. As a result of this experience, a highly refined computerized program for plumbing configuration design has been developed that results in minimum stress, allows for thermal growth and minimized vibration resonances, and calculates proper placement of brackets to dampen any residual vibration. A more detailed discussion of this program is presented in Volume III, Report B, Section II.

4. Combustible Fluid Drains

The gas-generator fuel manifold lines are automatically drained overboard by a dump valve when the engine is shut down. When the cutoff lever is in the OFF position, the dump valve is opened by a positive hydraulic signal from the fuel control, which allows residual fuel to drain from the fuel manifolds. This prevents accumulation of raw fuel inside the engine and also minimizes the possibility of varnish and carbon deposits in the manifolds.

Drain valves are also provided in the gas-generator and duct heater combustors to drain any residual fuel by opening automatically when combustor pressure decreases to sea level pressure.

5. Fire-Shield Provisions

Provisions are made for mounting a fire shield on the outer circumference of the engine case just forward of the rear mount to isolate the hot engine cases from the nacelle cavity to reduce fire possibilities.

K. GROUND SAFETY

Maintenance hazards analyses are conducted to identify, evaluate, classify, and resolve hazardous tasks. All hazards are eliminated, if feasible; where not eliminated, service publications such as Maintenance and Overhaul Manuals contain data concerning those hazards in the form of precautionary notes and procedures. A set of instructions containing precautionary notes, as applicable, for engine loading and unloading from the shipping stand of the engine and ground handling, will accompany each JTF17 engine shipped by P&WA.

All engine accessories are designed for removal in accordance with MIL-STD-803A requirements for personal safety.

L. PERSONNEL SAFETY

To minimize hazards during ground handling, precautionary notes are inserted in maintenance manuals and handbooks. Some of these items are as follows:

1. Precautionary notes concerning the dangers associated with the inspection of engine inlets and exhaust.

2. Descriptions of hazards involved with fuel handling and possible skin-irritation effects.

3. Methods for the protection of personnel from radiation effects during the use of radioisotope equipment.

M. FAILURE ESCALATION

The minimum possibility of failure escalation is provided by the following redundant and fail-safe features, which are incorporated into the design of the JTF17 engine. Their primary function is to enhance safety by minimizing the escalation of specific failures into hazards of a critical or catastrophic nature.

1. Main Rotors

Main rotors are designed so that in the event of a main bearing failure, overspeed will not result because of uncoupling the turbine rotor from the compressor rotor. The following design features ensure this fail-safe characteristic:

- The low-speed rotor is prevented from uncoupling by a fail-safe shaft system using a main thrust bearing sleeve arrangement. If a thrust bearing failure is experienced, resulting in severing the outer sleeve, the inner torque-carrying shaft remains intact.

- The high-speed rotor is designed so that if shaft separation occurs, the axial spacing of the blades and disks is set so that the rotating airfoils will contact the stationary airfoils before any disk contact is made. This will prevent overspeed and/or subsequent rupture of any disk.

2. Main Bearing Hydrostatic Seals

The main bearing hydrostatic seals have redundant labyrinth seals that are pressurized and cooled by low-temperature fan discharge air to a temperature level equal to or less than that experienced on current commercial jet and fan engines. Thus, hot gases are restricted from entering the bearing compartment where they might possibly cause a fire or overheat the bearing in the event of seal failure.

3. Fuel, Oil, and Hydraulic System Filters

The fuel, oil, and hydraulic system filters are designed with reserve capacity and the large filters are provided with bypass valves to prevent engine shutdown in the event of excessive filter blockage. The main oil pump filter and the fuel pump and hydraulic filters have pressure pickup provisions for monitoring pressure drop, thereby warning of operation under a bypassed condition.

4. "Last Chance" Oil Screens

"Last chance" oil screens are used at all bearing locations to prevent clogging of oil system pressure jets (which could lead to bearing failures) because of the inadvertent admission of foreign particles in the engine external plumbing.

5. Redundant Ignition System

A redundant ignition system is used. The main engine and the duct heater burner have two spark igniters each and two ignition exciters, a nough only one of each is required for ignition. Provision for checking igniter firing is included to ensure redundancy prior to each takeoff.

6. Duct Fuel Flow Shutoff

Safety features are incorporated to shut off duct fuel flow automatically in the event of a duct heater flameout, and to reduce gas-generator fuel flow in the event of low rotor overspeed. In addition, in the event of a gas-generator flameout, shutdown of the duct heater automatically takes place when N_2 speed decreases to 80% of maximum predicted value.

7. Loss of Duct Heater Nozzle Actuation

If loss of duct heater nozzle actuation is experienced, the nozzle will assume the full-open position rather than the full-closed position, thus preventing compressor surge.

8. Aerodynamic Brake

An aerodynamic brake is provided that will reduce rotor speeds upon engine shutdown at high ram pressure ratios to preclude escalation of damage.

9. In-Flight Monitoring and Recording

Provisions for in-flight monitoring and recording of selected parameters are incorporated. It is anticipated that recordings of these parameters will be made on tape, signal-conditioned and fed into an airborne computer so that engine health can be immediately determined on touchdown. To minimize the quantity of data collected, only out-of-normal-limits data would be recorded (except baseline data taken at the beginning and end of each flight).

10. Secondary Air Velocities

Minimum secondary air velocity requirements are established to prevent spontaneous ignition of any fuel-air mixtures that might collect in the engine nacelle cavity.

11. Safe Engine Operating Limits

Safe engine operating limits, including allowable time limits with zero oil pressure, are specified in Service Manuals.

12. Thrust-Reverser Interlocks

Thrust-reverser interlocks are provided so that inadvertent forward or reverse thrust cannot be imposed by the thrust reverser or by loss of the thrust reverser actuation force.

N. WHEELS-UP LANDING CONSIDERATIONS

All large-volume fuel or oil-carrying components are located away from the bottom of the engine to preclude escalation of damage from fire in the event that a wheels-up landing was required.

SECTION V
SAFETY ASSURANCE TASKS

Safety analyses and reviews are performed by the Design Safety Group under the direction of the Program Safety Engineer to identify, evaluate, classify and resolve any safety hazards that appear during the design and development phases of the JTF17 engine program.

A. SAFETY FAILURE MODE AND EFFECT ANALYSES

A Safety Failure Mode and Effect Analysis is made to determine the effects upon engine operation and system operation of a functional failure or performance degradation of the engine subassemblies. Hazards are classified according to the definitions presented in the Appendix. All subassemblies that receive a critical or catastrophic hazard classification are redesigned to eliminate or reduce the hazard.

B. DESIGN LAYOUT REVIEWS

The detailed subassembly and assembly design layouts are reviewed from the overall engine safety point of view and approved by the JTF17 Safety Engineer or his delegate. These design reviews assure that design safety criteria are incorporated and that design weaknesses are identified and corrected. If he cannot approve the layout, he prepares a Safety Engineering Layout Review (SELR) setting forth his concerns (as shown in figure 2) and requesting:

1. Additional analysis or study or a minor change in design (in which case the layout is immediately returned to the designer)

2. Specific safety tests which are added to the Test Requirements following which he approves the layout

3. A major change in design which is referred to the Configuration Management Board for review.

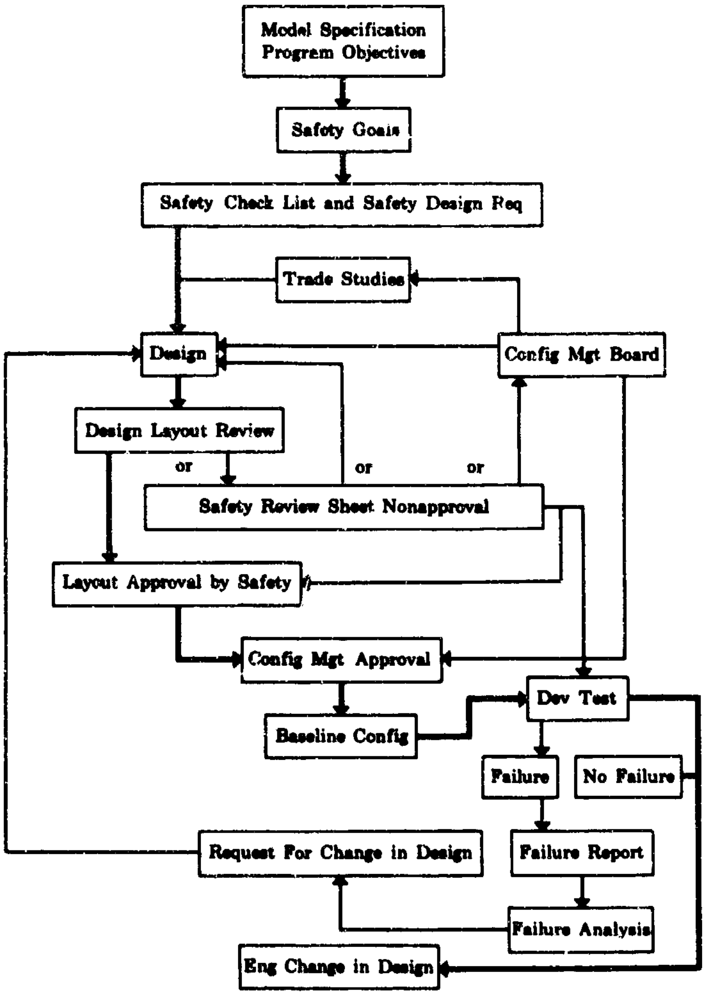


Figure 2. Phase III Safety Assessment Procedure Loop

FD 16845
CV

The Configuration Management Board reviews the SELR, the layout and the desi... Trade-off Studies and

1. Requests a new Trade-off Study

2. Directs a major change in design

3. Rejects the concerns expressed on the SELR and directs the JTF17 Safety Engineer to approve the layout.

Any safety hazard uncovered by these reviews is immediately brought to the attention of the Program Manager, the Chief Design Engineer, and the pertinent designers. Follow-up by the JTF17 Safety Engineer continues until the identified hazard is resolved. To resolve the identified hazards, either design changes or the methods described in Paragraph K, Post-Analysis Action, are specified. All identified hazards that are critical or catastrophic in nature are immediately resolved and reported to the FAA, as delineated in Section VI.

C. VENDOR CONTROL

Component safety and reliability considerations are provided by inclusion of the following statements in each Vendor Purchase Specification:

1. The design of this component shall be in accordance with applicable paragraphs of MIL-STD-785.

2. The design shall be optimized from a safety engineering point of view and it shall be a requirement that all hazards have been minimized. To the maximum extent possible, this effort will use data developed in compliance with the reliability program requirements. All hazards identified by this analysis will be reported to P&WA by the vendor for resolution.

3. A detailed description of how safety considerations are complied with by each vendor can be found in Volume III, Report B, Section III, Paragraph O.

D. SAFETY DEMONSTRATION DURING DEVELOPMENT TEST PHASE

The basic saf ty and reliability of the powerplant is verified through comprehensive testing under the direction of the JTF17 Project Engineering Group. Major emphasis is on both full-scale engine testing and subassembly testing. Subassembly testing is employed to permit off-design operation to determine safe operating margins and multiplication of experience on vital subassemblies beyond that which is obtained by full-scale engine testing. Such subassemblies include compressors, combustion section, turbine, bearings, seals, accessory drive system, and all fuel system components. These subassemblies are tested in a simulated service environment and also at overstress conditions. Report E, Section I of this Volume presents a detailed description of these planned tests.

In accordance with established practice, P&WA maintains a detailed record of each vital part on each experimental JTF17 engine as outlined in Exhibit E of Report F, Section II (Reliability Program). This record follows the part throughout its development life, showing the identity of the engines in which it has been installed, the duration of its installation, and its accumulated time in operation. This information is updated at each engine disassembly. Inspection deviations are also recorded. Serial numbers are assigned to each vital part so that information concerning source, material heat, and materials control is always available. This information is used in the evaluation of part reliability and durability.

Pertinent data concerning failures or safety incidents occurring during the development program are transferred to a failure report by the cognizant test engineers and forwarded to the cognizant Program Management personnel, including the JTF17 Safety Engineer. The failure reports are analyzed by personnel in the Design Safety and Reliability Analysis Group. All information on failures is stored in a central data file.

Failure encountered during the development programs are reviewed by the Project Engineering Department in coordination with the Program Safety Engineer and other cognizant personnel. Results of the review are submitted to the Design Department for analyses and corrective action. Prompt and thorough attention is given to the problem area, especially those that may constitute a hazard. Corrective action is initiated by the issuance of an Engineering or Design Memorandum approved by the Program Manager or his delegate. An Engineering Change is released after engine substantiation testing has proved that the change has corrected the problem.

The flow of data from the issuance of the Model Specification and the assignment of safety objectives through design and Configuration Management is shown in figure 2. It should be noted that any change affecting the safety of the baseline configuration cannot be processed without the approval of the JTF17 Safety Engineer except by appeal to the Configuration Management Board.

Emphasis is placed on safety considerations relative to improper installation of components, incorrect connections for plumbing, misalignment of control cables or interference of one component with another.

Wherever possible,designs will be established to prevent the improper assembly of a component by foolproofing the design. For example, it will be impossible to install a filter element upside down. Plumbing connections will be sized so that incorrect end points cannot be inadvertently mated.

If errors in installation are experienced during development testing, the effects of improper maintenance are analyzed and design changes incorporated to preclude hazardous effects of misrigging or faulty installation of components.

E. DELIVERY PHASE

The Program Manager, through the Program Safety Engineer, Quality Assurance, and Purchasing Departments, controls the safety and reliability aspects of the production of the JTF17 engines by the application of appropriate raw material and finished part quality control procedures and through the selection of qualified vendors for critical materials and parts. Acceptance testing is used as the ultimate safety assurance feature.

1. Engineering Changes for Delivery Engines

After the JTF17 engine has been qualified and an Assembly Parts List Complete for delivery engines has been established, Engineering Changes cannot be released without the Program Manager's specific authorization. This authorization will occur only after the new part has been appropriately qualified and substantiation testing accomplished. Revisions to the Assembly Parts List Complete shall be accomplished by following established Configuration Management Procedures (see Volume V, Report C).

2. Acceptance Tests

Production testing is part of the overall reliability and safety assurance program. Surveillance and run-in tests are conducted on critical parts and subassemblies, such as fuel controls and all main thrust bearings prior to final engine assembly. All JTF17 engines will be fully assembled and tested under simulated operating conditions to detect possible errors of workmanship or defective parts and to ensure the correctness of the assembly technique.

3. Quality Assurance

Quality Control is directed by the Product Assurance Manager reporting directly to the Program Manager. Under his direction, the Chief of Quality Assurance establishes production inspection and quality control standards based on JTF17 engine system requirements, results of the development phase, and previous experience with similar parts (see Report F, Section III).

F. OPERATIONAL PHASE AND TRAINING CONSIDERATIONS

Safety Engineering objectives during airline operation are to continue surveillance of operating experience, to recognize incipient safety hazards, and to initiate corrective action before incidents occur. To attain this objective, three principal methods are utilized:

1. Establishment of an active failure reporting and analysis system

2. Thorough training of personnel to avoid hazardous engine operation or maintenance procedures

3. Issuance of timely and comprehensive manuals and publications to disseminate safety information.

1. Failure Reporting, Analysis, and Corrective Action

Pratt & Whitney Aircraft Field Representatives at commercial installations assist in providing fast and accurate failure and incident reporting required for action on safety items. Input from the incident will be used for long-range statistical studies.

Failures or safety incidents occurring in JTF17 engines in service will be formally reported to Pratt & Whitney Aircraft in Field Service Reports. Copies of these reports will be sent immediately to the Program Manager through the Program Safety Engineer, as well as to the Service Records Group. The Engineering Liaison group of the Service Department will deal directly with the Program Manager and the Program Safety Engineer on problems requiring immediate action. Corrective action will be initiated in the same manner as if these failures were found in a development program. The Service Representative will conduct an analysis of the failure and, when required, Project Engineering specialists will be dispatched for more detailed, on-the-spot analysis. If necessary, the failed parts will be delivered to Pratt & Whitney Aircraft for the same thorough analysis given to failed experimental parts.

The Service Records Group will categorize the information from the Field Service Reports and transcribe it onto punched cards from which reports can be generated on demand. The Service Investigation Group will analyze failed parts received from the field in cooperation with the Project Engineering Organization. Corrective action required as a result of service failures will be initiated by Engineering Order Supplement and, when substantiated, will take the form of an Engineering Change, Service Bulletin or an updating of the Service Manual.

In addition to service data from the JTF17 engine, Pratt & Whitney Aircraft's Service Representatives will provide data input from other Pratt & Whitney Aircraft engines in service. These data, as supplied by the Engineering Liaison Group of the Service Department to Project Engineering through the Program Safety Engineer, will provide additional experience to be used in achieving maximum safety.

2. Training and Training Equipment Requirements

Training task analyses, resulting in the establishment of training and training equipment requirements, will be performed by the Service Department. In these analyses the training and training equipment for safe flight operating procedures, ground handling, ground operation, and maintenance of the JTF17 engine will be identified and analyzed. These training methods are more fully discussed in Report F, Section VI, paragraph J.

3. Technical Publications

Service publications, such as Maintenance and Overhaul Technical Manuals and other technical orders, will include safety data that have been generated during the Development Phase of the JTF17 Program. In all these publications, precautionary notes will be included as required. These publications will be produced and distributed in sufficient time prior to engine delivery to achieve maximum service and training utilization.

G. AIRFRAME/ENGINE INTERFACE

Safety aspects of the airframe/engine integration will be continuously monitored and periodically reported in accordance with the milestone chart, figure 3. Safety coordination conferences with the airframe manufacturers have been conducted during Phase II-C. System safety planning agreements have been included in the Interface Compatibility Agreement negotiated with the airframe contractor for Phase III. The agreement sets forth the understanding of the parties with regard to their responsibilities for a system safety program. Coordination in accordance with the agreement will continue in Phase III. The reader is referred for details to copies of the agreements which are included in the airframe contractor's proposal.

H. MAINTENANCE HAZARD ANALYSES

The maintenance hazard aspects of the design are reviewed to assure the identification, evaluation, classification, and resolution of hazardous tasks. These reviews are accomplished by the Design Maintainability Group base [illegible] on Service Representatives reports. An investigation is then init [illegible] to determine the feasibility of eliminating the hazardous tasks by de [illegible] anges. Special procedures, such as the incorporation of adequa [illegible] cautionary notes in the Maintenance Manuals, are established to res [illegible] ve the hazardous tasks when the incorporation of design changes is not feasible or until the pertinent engineering change parts have been incorporated. All identified hazards that are classified as critical or catastrophic in nature are immediately corrected and reported to the FAA by monthly report.

I. EMERGENCY PROCEDURE ENGINEERING REVIEW

Instructions for safe operation and emergency procedures are prepared by the Installation Engineering Group with technical direction from Program Management. These Operating Instructions are issued by Service Publications Department to the airframe manufacturer and airline who in turn incorporate the information in the Flight Manual. Engineers from the P&WA Flight Operations Group make frequent visits to each airline to ensure proper application of operating procedures. The Program Safety Engineer conducts a review to determine that engineering instructions for emergency procedures are consistent with safety requirements.

J. ACCIDENT/INCIDENT REVIEWS

The accidents/incidents that occur during the development phase will be reported to the Program Safety Engineer for corrective action follow-up. The nature and cause of the accident or incident will be investigated to determine the cause and the recommended method for resolving the situation. Accidents and incidents that result from an engine safety deficiency and are considered critical will be reported to the FAA in the form of Accident/Incident Reports that will be submitted at each occurrence. For a discussion of these reports, see Section VI.

K. POST-ANALYSIS ACTION

Redundant and fail-safe features are employed, where feasible. Where hazards cannot be avoided in this manner, warning devices and emergency operating procedures are incorporated to contain and neutralize the effects of the safety hazards and to prevent the progression of a hazard into one of more critical nature. These are documented in applicable manuals and publications.

If a serious hazard exists such that an engineering change delay cannot be tolerated, special procedure cycles or time limitations will immediately be put into effect until an engineering change can be processed.

SECTION VI
SAFETY REPORTS

The following safety reports will be prepared and submitted to the Federal Aviation Agency by the Design safety analysis group at the direction of the Program Safety Engineer.

A. PROGRESS REPORTS

Safety progress reports will be prepared as a part of the monthly Progress Report. These reports will summarize all safety efforts accomplished since the previous progress report and will list the analyses and reviews to be undertaken during the next report period. A summary of all identified hazards and hazardous tasks will be reported along with the status of the corrective action.

B. ACCIDENT/INCIDENT REPORTS

A report containing all facts pertinent to the accident/incident will be submitted at each occurrence. The corrective action being taken to preclude the possibility of recurrence during engine transportation, ground handling, and flight operation will be included. Reports will be submitted as part of the monthly progress report, on a periodic basis, summarizing engine accidents or incidents that are considered to be of a critical or catastrophic nature.

SECTION VII
SYSTEM SAFETY ENGINEERING MILESTONES

To ensure the accomplishment of safety engineering tasks, the following safety milestone events will be established to monitor the progress of the safety engineering plan for the JTF17 Engine Program. Milestone events are integrated with the overall program plan. Figure 3 shows the length of time from the start of Phase III until the accomplishment of the following milestone events.

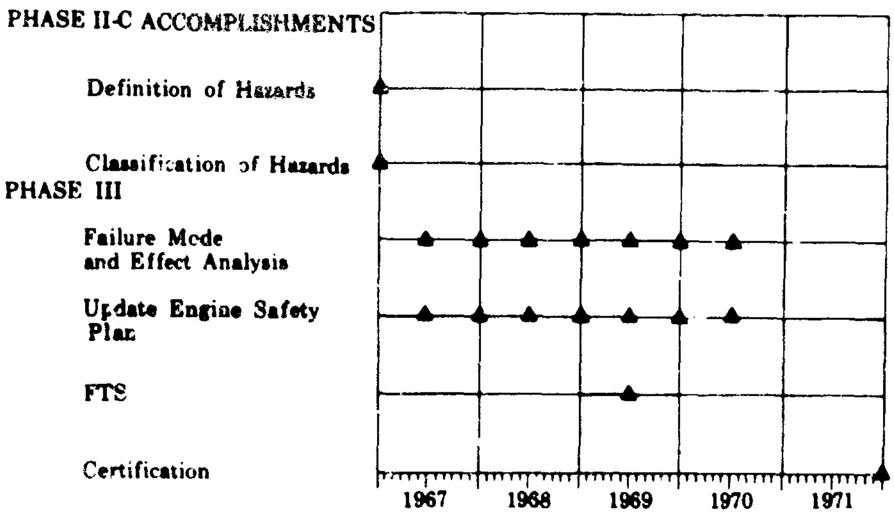


Figure 3. Safety Milestone Chart

FD 16516
CVII

A. PHASE II-C ACCOMPLISHMENTS

As shown in the Milestone Chart (figure 3) some of the Safety tasks have already been accomplished. Two demonstrator engines have been assembled and tested. Radioisotope inspection has been put to practical use during the testing of these two engines by producing X-ray films of variable stator vanes in the compressor to ensure the safe operation of the engine.

Special fiber-optic borescopes have also been extensively used to verify the integrity of the compressor, burner, and turbine areas.

As explained in Section IV, Paragraph J, a complete fire analysis has been made of the engine installed in the nacelle.

Safety planning and coordination with the airframe manufacturers has taken place and exhibits to the airframe/engine contractual interface documents have been negotiated.

B. PRELIMINARY DESIGN REVIEW FOR PHASE III

After award of the Phase III contract, a Preliminary Design Review will be conducted in coordination with the FAA and the airlines to effect complete understanding of the Safety Requirements of the design.

C. TEST DEMONSTRATIONS (FTS)

The successful completion of the Flight Test Substantiation (FTS) will verify the airworthiness and safety of the prototype engines for experimental flight operations. At the time of the FTS, the safety tasks listed in Section V will be completed as applicable to the FTS engine design. The results of these tasks will be submitted to the FAA in the form of progress reports, (see Section VI).

D. CERTIFICATION TEST

The successful completion of the Certification Test will verify the airworthiness and safety of the production model engines.

APPENDIX
HAZARD CLASSIFICATION DEFINITIONS
(AS APPLICABLE TO JTF17 ENGINE)

1. SAFE HAZARD

Personnel errors, design deficiencies or subsystem/component malfunctions that will not produce noticeable inflight effects on the JTF17 engine or result in personnel injury shall have a hazard classification of "safe."

2. MARGINAL HAZARD

Personnel errors, design deficiencies or subsystem/component malfunctions that will not result in personnel injury but are considered capable of producing a noticeable inflight performance degradation of the JTF17 engine shall have a hazard classification of "marginal."

3. CRITICAL HAZARD

Personnel errors, design deficiencies, or subsystem/component malfunctions that will result in an inflight shutdown of a JTF17 engine shall have a hazard classification of "critical."

4. CATASTROPHIC HAZARD

Personnel errors, design deficiencies, or subsystem/component malfunctions that are considered capable of resulting in serious personnel injury or an engine explosion, fire, or part of the engine becoming a projectile and passing through the outer engine cases with residual kinetic energy shall have a hazard classification of "catastrophic."

REPORT D
HUMAN ENGINEERING PROGRAM

SECTION I
HUMAN ENGINEERING PLAN

A. OBJECTIVE

The objective of the Phase III Human Engineering Plan is to integrate the principles of human physical and psychological characteristics into the engine and ground equipment design. This integration ensures that maximum man-equipment efficiency and safety is designed into all engine components and maintenance equipment.

B. SUMMARY

Human Engineering is primarily associated with maintainability, particularly in the improvement of engine assembly and maintenance. The Human Engineering plan is a continuation and expansion of the effort established in Phase II and is administered by the Chief, Maintainability and Human Engineering. Human Engineering is an identifiable function of each Maintainability group.

The Human Engineering effort is guided by MIL-STD-803 and emphasizes personnel convenience and safety, man-equipment accuracy and the combined man-equipment capability. The basic operations for accomplishing the goals of the Human Engineering Program are:

- Personnel orientation in Human Engineering Objectives
- Engine and equipment design review
- Continuing review of engine and component mockups
- Review of all engineering changes
- Survey of existing engines for improved Human Engineering features
- Investigation of internal and field problem reports.

In-flight factors, such as internal component containment and cabin air purity, are included in the safety program described in Report C.

C. ORGANIZATION

The Chief, Maintainability and Human Engineering, reports through the JTF17 Product Assurance Manager to the JTF17 Program Manager. The Product Assurance organization will produce positive management control of related disciplines of safety, reliability, maintainability, quality assurance, human engineering and standardization. It is an organization well suited in coordinating the airframe, engine, airlines and Federal Aviation Agency requirements in these areas. The assignment of a single individual responsibility for each discipline will improve communications between Pratt & Whitney Aircraft and the organizations named above. The Product Assurance organization is described and illustrated in Volume V, Report I.

The Chief, Maintainability and Human Engineering directs and controls all the tasks described in this Human Engineering Plan. The departmental Human Engineers from the Design Engineering, Engineering Operations and Product Support departments take their direction from the Chief, Maintainability and Human Engineering for the JTF17 Program. The departmental Human Engineer directs and controls all the tasks within his department. The Design Engineering representative directs all tasks related to engine component design. All production tasks are directed and controlled by the Engineering Operations representative through the Process Planning, Tool Design, Facilities, Manufacturing and Test Engineering Groups. The Human Engineering tasks pertaining to engine maintenance are directed by the Product Support Group.

The organizational breakdown for the implementation of this plan is shown in figure 1.

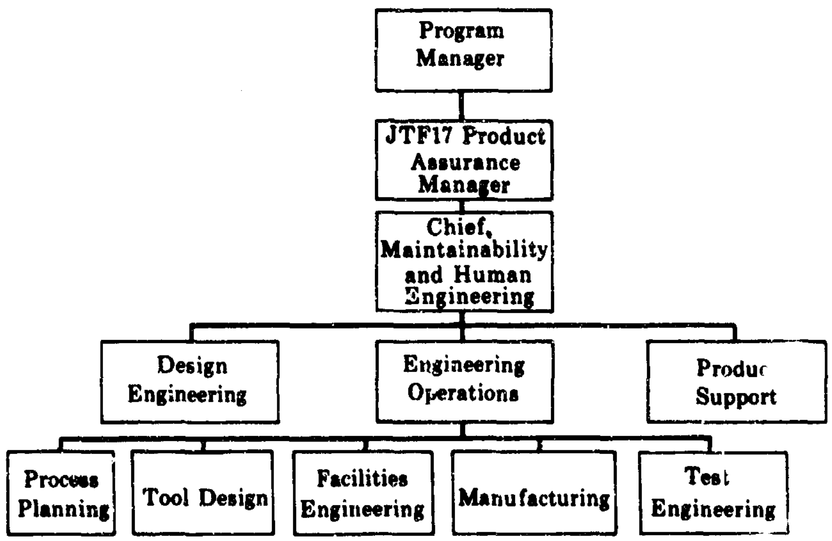


Figure 1. Human Engineering Program Management FD 16290
DI

D. ESTABLISHMENT OF HUMAN ENGINEERING CRITERIA

The Human Engineering function promotes engine and equipment designs and operational procedures that incorporate Human Engineering principles affecting personnel safety and convenience, man-equipment accuracy, and the combined man-equipment capability. Detailed design criteria have been established by the above considerations and are listed below.

1. Design Considerations for Manufacturing and Maintenance Operations

The design of engine components and equipment to emphasize personnel convenience during manufacturing and maintenance operations is aimed at providing the following:

- Adequate engine access space and interface connections for assembly and maintenance

- Accessibility and visibility of high maintenance areas such as filters, inspection points, adjustments, connectors, and identification labels; sufficient space for the use of required tools or equipment without difficulty or hazard.
- Time-cost-performance trade studies in the areas of equipment reliability and decreased personnel requirements.
- Manufacturing and maintenance equipment factors for size, weight, standardization and simplicity.

Portable equipment and tools must be limited in size and weight to permit convenient handling. The equipment size and configuration depends upon its function; however, all tools, equipment or components in excess of 45 lb must incorporate lifting and handling provisions. All equipment must be standardized to include consistent use of color codes, dials, gages, switches, levers, and basic control panel layouts. To increase man-equipment effectiveness and reliability, equipment is designed to minimize complicated operational procedures. Equipment notations and instructions are in convenient locations and are legible and meaningful.

2. Avoiding Hazardous Operations

A review of engine components and equipment is made to eliminate hazardous operations and to ensure personnel safety during manufacturing, handling and maintaining the engine. The review ensures that:

- Unnecessary sharp edges or corners on engine components are eliminated. Where sharp edges, sharp corners or labyrinth seals are required, protective covers are provided for handling and storage.
- Engine assembly and maintenance procedures will not require any unnecessary personnel contortions.
- The engine incorporates adequate warning devices to provide personnel safety during manufacture, maintenance and flight operations. External components and plumbing have identifying markers for types of fluids, electrical components and hot areas. The engine incorporates the necessary detection equipment to transmit malfunctions during test or flight.
- Manufacturing and maintenance equipment is arranged so that the operator is not required to reach through or around hot, cold, electrical, or rotating parts. All such components are identified and shielded.
- Fail-safe designs are incorporated in all equipment where failure could result in injury to personnel. All electrical equipment incorporates overload limiters to prevent overheating and possible fire. Cranes and hoists contain automatic braking devices that would lock in the event of electrical or mechanical failure of the lifting equipment.
- Equipment and work areas employ applicable warning markers. Handling equipment reflects weight capacities and lift instructions. Equipment and work areas carry instructions

and markings for electrical and pipe line identification, no-step or -walk areas, existing mechanical hazards, and toxic area.

3. Accuracy of the Man-Equipment Combination

An evaluation of the equipment capability is made to determine if the accuracy of the man-equipment combination is within the allowable tolerance limits of the engine component. Necessary personnel technical training and refresher courses in the equipment operation are made to provide maximum man-equipment accuracy.

4. Man-Equipment Compatibility

Man-equipment compatibility is facilitated by relating the personnel physical and intellectual requirements to the equipment design and operation. Engine access areas and equipment layout design conform to operation and maintenance personnel whose body dimensions fall between the 5th and 95th percentiles per MIL-STD-803. Existing field maintenance equipment will be used in all possible cases to reduce personnel retraining requirements. New equipment operational requirements will be established similar to existing equipment.

E. PROCEDURE

The procedures as shown in figure 2, Human Engineering Flow Chart, were established to ensure the proper integration of the Human Engineering criteria into engine and equipment design.

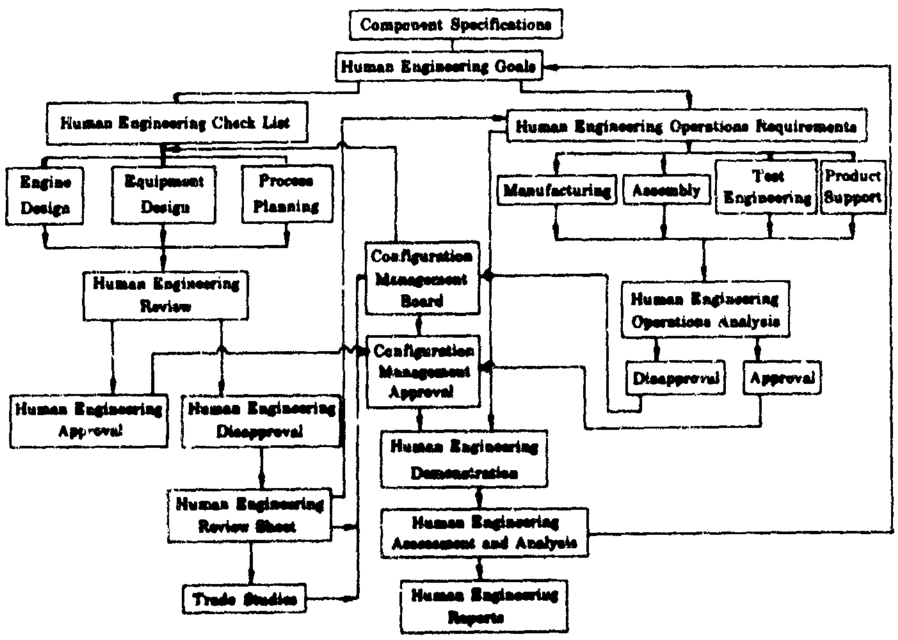


Figure 2. Human Engineering Flow Chart FD 17533 DI

1. Component Specifications

The engine Component Specifications are established by performance requirements and envelope coordination with the customer.

2. Human Engineering Goals

Once the Component Specifications are established, the component is surveyed to determine the required Human Engineering goals. The basis for these goals is obtained from MIL-STD-803 and Human Engineering experience in the manufacturing and maintenance obtained from subsequent commercial engines. The goals are prepared by the Chief, Maintainability and Human Engineering and approved by the Manager, Product Assurance.

3. Human Engineering Checklist

The Human Engineering goals are reduced to basic requirements and tabulated in the form of a checklist. A typical engine design checklist is presented in Section III.

The checklists are distributed to the engine component designers, ground equipment and tool designers, and manufacturing process planners as guides for establishing standard precautions and requirements necessary to achieve the Human Engineering goals.

4. Human Engineering Review

At the completion of the design phase, the Human Engineer reviews all engine or equipment designs and operation summaries to detect problem areas affecting Human Engineering requirements. When no such areas exist, the design receives the Human Engineering approval. In the event a problem area is detected, the Human Engineer prepares a Human Engineering Review Sheet (HERS) and initiates follow-up action which may include:

- Discussing the area with the designer or planner and establishing alternative configurations or operational approaches.
- Consulting other affected departments to determine space and instrumentation requirements, necessary equipment provisions and overall design intent.
- Reviewing related service department data, such as existing field summary reports and maintenance manuals, to determine past experience and solutions to the particular problem.
- Performing tradeoff studies for alternative solutions to determine their effects on performance, cost, weight, reliability and maintainability.
- Weighing the results of the trade-off study against the desired Human Engineering feature to determine the most practical solution.

Changes are proposed to the Designer or Process planner and, in case of disagreement, to the Configuration Management Board based on the above studies.

5. Configuration Management Board

The Configuration Management Board is comprised of Design and Project Engineering personnel. This board meets weekly to review problem areas and proposed engine or equipment changes.

The Configuration Management Board reviews the HERS along with the related supporting studies and

- Directs a change in design.
- Rejects the proposal and directs the Chief, Maintainability and Human Engineering, to approve the design.

Following design or Engineering Change approval by the Chief, Maintainability and Human Engineering, or his delegate, further approval is in accordance with the system in the Configuration Management Plan, Volume V, Report C.

6. Program Review

a. P&WA Design Review

To assure that the benefits from our past experience accrue to the design and development of the JTF17 engine, P&WA will hold design reviews by the P&WA Design Review Board. This review will be in addition to the procedures discussed above.

The P&WA Design Review Board, made up of experienced Program Managers and other senior Development Engineers from FRDC and East Hartford, will meet periodically according to a schedule established on the basis of major design accomplishments.

The Board's principal function in Phase III, as it was in Phase II-C, will be to contribute suggested solutions to SST development problems, and to review the design to assure that problems that arise or have been previously experienced on other programs are not inadvertently designed into the SST.

b. Major Program Reviews

Major Program Reviews will be established in Phase III to provide for Government, airlines and airframe visibility and participation.

These Major Program Reviews will be discussed in detail in the Configuration Management Plan (Volume V, Report C). Although specific reviews as such were not held in Phase II-C, P&WA did consult with the Government, airline and airframe representatives and these informal discussions will also be continued in Phase III.

The Configuration Management Plan points out that should a valid design consideration have been overlooked by either the Design Review Procedures or the P&WA Design Review, it should be uncovered by the FAA/Airframe/Airlines review.

7. Human Engineering Operations Requirements

The Human Engineering Operations Requirements are established by the Human Engineering goals and the Human Engineering design features. These Requirements are established as performance guidelines for the manufacturing, assembly, test and field maintenance operations analysis.

8. Operations Analysis

The Operations Analysis is conducted by Human Engineers in the Manufacturing, Assembly, Test and Product Support Groups. The purpose of this analysis is to assure that the Design Human Engineering requirement are accomplished under actual working conditions. The Human Engineer reviews the production or maintenance operations and procedures to compare the accomplishments with the initial Human Engineering goals.

In the Manufacturing Department, the Human Engineer reviews the manufacturing operations to ensure that the operational procedures can be performed in an efficient, safe and accurate manner. The review includes all areas of machining, fabrication and equipment handling.

The Human Engineer in the Assembly Department reviews all areas of engine and component assembly for proper execution of Human Engineering principles as follows:

- Sequence of assembly operations to ensure that the assembly procedures employ maximum man-equipment efficiency and incorporate adequate personnel safety precautions.
- Difficult assembly areas to determine cause and possible procedural, equipment or component changes to reduce the error potential.
- Areas of recurring errors to determine cause and possible procedural, equipment or component changes to eliminate ambiguities and reduce the error potential.
- Tool handling requirements to ensure that the tool was properly designed to fit the operation and the operator.
- Operation and tool standardization to ensure that similar assembly tasks and tools are comparable in procedures and operations. Whenever feasible, tools required to perform the same function in different applications are designed to be interchangeable. The aim of operation and tool standardization is to conveniently train the man in many related tasks, thereby increasing the overall personnel effectiveness.

In Test Engineering, the Human Engineer surveys the Human Engineering features associated with transporting, mounting and testing the engine. His main interest areas are:

- Procedures for mounting the engine or component into the test cell. Adequate handling and attachment provisions on the transporting equipment to conveniently mount the engine or component in the test facility with adequate personnel safety precautions.
- To provide the necessary coordination between engine and test stand design to maintain accessible locations of such external connections as power takeoff points, fuel, air and instrumentation connections and starter interfaces; verification of convenient and accessible locations for external maintenance items.
- Testing procedures to establish the existence of a fail-safe operation, adequate warning features to signal engine malfunctions, and consistent use of equipment throughout the engine and component testing facilities; adequate protective equipment and precautionary procedures for personnel working in the testing area.

The Human Engineer in the Product Support Groups serves as the direct link between the Human Engineering operation and the customer or field maintenance facilities. He reviews complaints and customer summary reports to establish existing Human Engineering problem areas.

In the event the above Human Engineers determine an operation or procedure is inadequate to satisfy the required Human Engineering goals, the information is forwarded to the applicable Design or Planning Group for corrective action. All approved operations and procedures reports are forwarded for Human Engineering demonstration.

9. Human Engineering Demonstration

The Human Engineering Group receives input data from Human Engineering Operations Requirements and the Operations Analysis. After compiling the requirements for demonstration from the above data, this Group demonstrates the Human Engineering effort for each engine section. This demonstration is accomplished by actually following the section through the manufacturing, assembly and test phases and evaluating the degree of the Human Engineering achievement.

10. Human Engineering Assessment and Analysis

Based on the results of the Human Engineering Demonstration, the Human Engineering accomplishments are weighed against the initial goals to determine the overall effectiveness of the Human Engineering effort. The results of this assessment are used to determine if operational or procedural changes are required to accomplish the intent of Human Engineering goals.

11. Human Engineering Reports

The Human Engineers in the above operations groups summarize their review findings for distribution and approval by the Chief, Maintainability and Human Engineering. Review data pertaining to the engine design is forwarded to Design Engineering. Information pertaining to machining operations, equipment handling, tooling, assembly or testing equipment is sent to Engineering Operations. This information is used to establish the requirement for a revision to a present design or operation and to establish Human Engineering requirements in future designs. The Chief, Maintainability and Human Engineering, will initiate engineering change requests as required to incorporate new or improved Human Engineering features into the engine and its ground support equipment.

Human Engineering prepares related technical reports and interoffice correspondence including Human Engineering Plan updating, summaries of internal and field maintenance data and problem area reports. These reports provide backup data for subsequent Human Engineering changes.

The Chief of Maintainability and Human Engineering submits periodic progress reports of the Human Engineering effort to the Product Assurance Manager.

12. Engine Mockup

The Human Engineer uses an engine mockup built and maintained to current engine status to locate external components and access points. Periodic reviews of the mockup are performed to establish the effect of engine changes on existing Human Engineering features.

13. Review of Engineering Changes

The Human Engineer reviews all engineering changes for possible effect on existing Human Engineering features. As described in the Configuration Management Plan, Volume V, Report C, the Chief, Maintainability and Human Engineering, approves all changes.

14. Personnel Orientation Classes

Personnel orientation classes are conducted by the Chief of Maintainability and Human Engineering or his delegate. The purpose of these classes is to outline the basic Human Engineering objectives and to relate the departmental responsibilities to the overall Human Engineering activity. Each designer or planner receives a Human Engineering Checklist outlining standard design precautions necessary to accomplish the Human Engineering objective.

SECTION II
SUMMARY FOR PHASE II

The Human Engineering effort in Phase II-C was primarily concerned with the provisions for efficient maintenance and inspection in the basic engine design. Mockups were used extensively in this effort. Representative results are described in the following paragraphs.

A. INSPECTION

Borescope bosses were located to facilitate inspection of the compressor, burner, and turbine components. Provisions were made for radioisotope inspection without hazard to personnel.

B. ACCESSIBILITY AND HANDLING

The engine was designed to be built up into sections prior to final assembly. This approach allowed maximum exposure of the component parts to the assembly personnel and minimum component weight for handling convenience.

External components, such as controls, valves, and gearboxes, were so located as to provide an adequate assembly and maintenance envelope, allowing convenient sufficient clearance for use of hand tools. External fittings and adjustments on the components were located to provide unrestricted access. Plumbing and other parts were located to allow removal of each component without prior removal of other parts.

Removable panels were located in the diffuser section of the duct heater assembly to provide access to the gas generator. The outer section of the diffuser is a split case made up of four 90-degree segments, whereas the inner section has four removable panels, each of approximately 10 x 38 in. size. Removal of the panels permits access to the gas generator for inspection and maintenance of the main fuel nozzles and bleed valves. A design study is currently underway to replace these access panels with ports in the outer duct for ease of removal.

To allow convenient inspection and maintenance of the main burner and 1st-stage turbine vanes, access is provided by telescoping the outer burner case and transition duct. These provisions are presently being evaluated to determine the most efficient access method.

C. CONVENIENCE AND SAFETY

Assembly/disassembly tooling fixture provisions were incorporated into all snap-fit areas.

The incorporation of lifting and handling provisions were provided in all P&WA-designed and vendor-furnished components weighing more than 45 lb.

D. ERROR PREVENTION

To prevent misassembly, each disk and spacer in the compressor has different fore and aft pilot diameters.

Engine case internal and external flanges contain offset holes for alignment purposes. Offset holes in the external flanges provide proper case alignment for plumbing and interface connections. The bearing compartment flanges incorporated offset holes to guarantee oil or air supply and drain line orientation.

SECTION III
CHECKLIST FOR ENGINE DESIGN

The following checklist is issued to the engine designer as an aid in the determination of standard design precautions and requirements necessary for good Human Engineering Design practice.

Each design is surveyed by the designer to ensure that these precautions and requirements have been satisfied prior to the layout review by the Human Engineer.

1. Marking, Labeling and Coding of Parts (Ref MIL-STD-803).

   a. Do part number markings, data plates, warning labels and codings follow an established pattern? (yes___ , no___ , n/a___)

   b. Are all parts, assemblies, or check points that must be frequently identified or inspected clearly labeled? (yes___ , no___ , n/a___)

   c. Is the labeling of a permanent nature, legible size and contrast, and accessible? (yes___ , no___ , n/a___)

   d. Is the wording used in labeling meaningful as to choice of words, technical terms and symbols? (yes___ , no___ , n/a___)

   e. Do abbreviations in markings or labels meet the requirements of MIL-STD-12B? (yes___ , no___ , n/a___)

2. Engine Assembly, Disassembly and Inspection.

   a. Does the design provide for rapid and easy assembly or disassembly by one individual? (yes___ , no___ , n/a___)

   b. Does the design minimize the number and variety of tools required for engine maintenance? (yes___ , no___ , n/a___)

   c. Are adequate tooling provisions incorporated for assembly or disassembly without difficulty or hazard? (yes___ , no___ , n/a___)

   d. Does the design avoid or minimize the use of blind connections? (yes___ , no___ , n/a___)

   e. Are replaceable units designed to be removed with standard hand tools, thereby minimizing the number of special tools required? (yes___ , no___ , n/a___)

   f. Are components of the same or similar form but differing in function designed to prevent physical interchangeability? (yes___ , no___ , n/a___)

   g. Are units which are subject to removal for inspection or maintenance located in accessible areas? (yes___ , no___ , n/a___)

   h. Are fasteners located so that they can be reached without prior removal of other parts? (yes___ , no___ , n/a___)

   i. Are captive fasteners used where access is difficult or a dropped fastener would be difficult to recover? (yes___ , no___ , n/a___)

j. Are assembly instructions concise and meaningful? (yes ___, no ___, n/a ___)

k. Is the design simplified to minimize the number of special assembly tools and procedures? (yes___ , no___ , n/a___)

l. Does the design provide ample clearance at screw or bolt locations to permit the use of power tools to minimize installation and removal time? (yes___ , no___ , n/a ___)

m. Are drains, filters and inspection ports visible during maintenance and accessible for removal and inspection? (yes___ , no___, n/a ___)

n. Has the use of screws in place of bolts been considered in limited or difficult access areas? (yes___ , no___ , n/a ___)

o. Are all offset flange holes for engine case alignment in the same location on all parts and clearly marked? (Preferably top vertical centerline area.) (yes___, no___, n/a ___)

p. Are electrical cables accessible for inspection and repair and are the connector alignment pin features clearly indicated to facilitate assembly? (yes___, no___, n/a ___)

q. Are all check points, drain and inspection point designs standardized? (yes___ , no___, n/a___)

3. Assembly Foolproofing

a. Are parts designed to prevent backward or reverse type installations? (yes___, no___, n/a___)

b. Does the design avoid parts that are so similar in appearance that an error in visual recognition could cause the wrong part to be installed? (yes___ , no___, n/a___)

c. Does the design avoid the use of two thread series such as .250-20 and .250-28 which could cause confusion and possible part damage by attempting to install the wrong series? (yes___, no___ , n/a___)

d. Does the design provide offset holes, steps, shoulders, dowels or markings to prevent improper assembly? (yes___, no___, n/a ___)

e. In such a case that mechanical foolproofing is impossible, is the part marked or coded to reduce the possibility of improper assembly? (yes___ , no___, n/a___)

f. Are electrical connections and plugs sized and pins arranged to prevent insertion into wrong part or with wrong alignment? (yes___ , no___, n/a___)

4. Safety Precautions

a. Does the design incorporate adequate handling and lifting provisions? (yes___, no___, n/a___)

b. Does the design eliminate all unrequired sharp edges and corners? (yes___, no___, n/a ___)

c. Are all fluid lines clearly labeled or coded as to contents, pressure, heat, cold, or other specific hazardous properties in accordance with MIL-STD-1247? (yes___, no___, n/a ___)

REPORT E
TEST

SECTION I
TEST INTEGRATION PLAN

A. OBJECTIVES

The objective of the Test Integration Plan is to assure that maximum overall system benefit will be achieved from all elements of the JTF17 development test program in the most economic fashion relative to program technical requirements, test facilities, schedules and manpower.

Major program objectives for Phase III include the demonstration of JTF17 engine performance in accordance with specification requirements, the development of engine durability and reliability to permit completion of the FTS on schedule and to conduct a continuing development program that will support the airframe contractors flight test program for 100 hours and that will demonstrate engine performance and durability characteristics such as to give reasonable assurance of the successful completion of Engine Type Certification in Phase IV.

B. SUMMARY

The major tasks of the JTF17 Phase III Development Test Program are:

1. Manufacture, assemble and test approximately 12 experimental engines
2. Demonstrate engine performance as defined in the Engine Model Specification
3. Demonstrate the durability and reliability required for FTS and for reasonable assurance that Engine Type Certification will be accomplished in Phase IV
4. Complete FTS test in June 1969
5. Deliver the 20 Ground Test and Flight Test Engines as defined in this proposal
   a. Deliver first Ground Test Engine in September 1968
   b. Deliver first FTS engine in July 1969
   c. Deliver last FTS engine in February 1970
6. Conduct a vigorous and comprehensive test program in support of the airframe contractors flight test program (100 hours).

An uninterrupted continuation of the development program as discussed in Volume V, Report A, Master Program Plan, would lead to the accomplishment of the following additional major tasks in Phase IV:

1. Demonstrate the engine performance as defined in the Engine Model Specification
2. Demonstrate the reliability and durability required for Engine Type Certification

3. Complete Engine Type Certification Test by 31 December 1971
4. Conduct a vigorous and comprehensive test program in support of the certification flight test program
5. Complete Airframe Certification by 15 May 1974
6. Conduct a comprehensive test program in support of the service requirements and to provide the basis for growth of the SST.

The anticipated hours of engine testing required to meet the test objectives outlined above are:

	FTS	End of Phase III	Engine Certification	End of Phase IV
Total time, hr	4,000	8,000	14,500	27,500
Heated inlet time*, hr	2,000	4,000	7,250	13,750
Maximum turbine inlet time, hr	2,400	4,800	8,200	16,500
Augmented time, hr	2,400	4,800	8,200	16,500
Simulated altitude Mach number time**, hr	1,600	3,200	5,800	11,000
Total number of active engines in program	12	12	15	15

To support the engine test program, component testing will be required. It is anticipated that the following component rig test time (approximately) will be required:

Component Time	FTS	End of Phase III	Engine Certification
Fan, hr	1,600	2,300	2,900
Compressor, hr	1,320	2,000	2,600
Primary combustor, hr	4,700	6,900	9,250
Turbine, hr	2,540	3,290	3,750
Augmentor, hr	2,460	3,220	3,970
Exhaust system, hr	3,150	4,600	6,150
Bearings and seals and gearboxes, hr	41,150	54,500	58,450
Controls and accessories, hr	46,000	90,000	137,000

*Heated inlet time is time with an engine inlet temperature equivalent to M 1.5 or higher.

**Simulated altitude Mach number time is time at cruise environment.

The extent of testing as listed above has been based on past experience, particularly that with the J58, as described in Volume III, Report E, Test and Certification Plan.

The milestones to be accomplished during this testing are given in the Detail Work Plan, Volume V, Report H.

The procedures and organization used for integration of the development test program in accordance with the objectives of this plan are described. The procedures and organization are basically identical to those that Pratt & Whitney Aircraft has successfully used on all of its previous engine development programs with changes introduced in recognition of the FAA's desire for adequate visibility.

C. ORGANIZATION

The program management system places total responsibility for the conduct of the development program in the hands of a single autonomous organization. The Program Manager has overall responsibility for the JTF17 engine including design, development, fabrication, delivery and support of the engine and associated hardware. He has complete authority and responsibility to meet the cost, schedule and performance requirements of the contract through his program organization. The complete program organization and line functional organizations are described in Volume V, Report I.

The Development Engineering organization for the JTF17 engine is shown in figure 1. The Manager, JTF17 Development, is responsible for directing the design and development of the JTF17 engine; that is, for design engineering, test and performance analysis, and fabrication of the JTF17 development engine. Project Engineers and Assistant Project Engineers, supported by competent Experimental Engineers, are assigned the responsibility for technical direction of the assembly and test of components, subassemblies, and the complete engine.

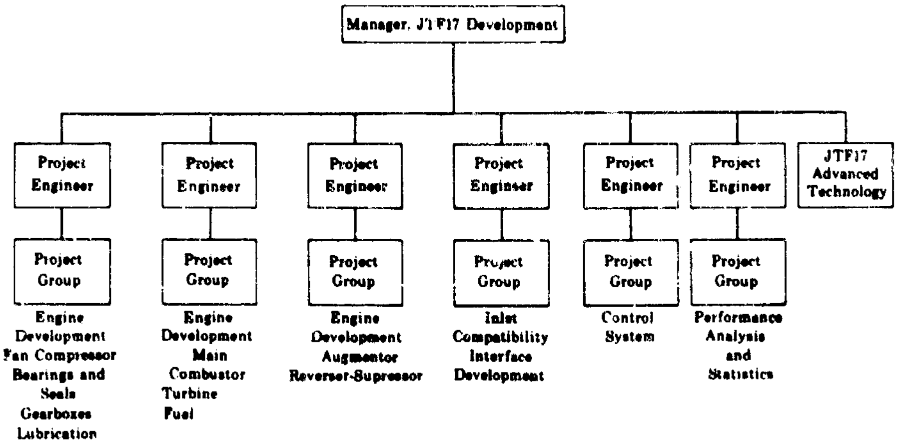


Figure 1. JTF17 Development Engineering Organization

FD 17751
EI

The Project Group is the basic organization that Pratt & Whitney Aircraft has used on all of its previous commercial and military turbine engine development programs. Most of the project and experimental personnel who will comprise the Phase III development organization have been assigned to the SST engine development for Phase II-C. The project engineering personnel to be assigned to the SST organization at the initiation of Phase III, as well as those currently assigned, have been selected to bring to this program a wealth of experience in previous commercial and/or military high Mach number development programs.

D. TEST PROGRAM

1. Summary

The Test Integration Plan provides assurance that the maximum benefit will be achieved from all phases of the test program in the most economical fashion with respect to technical requirements, test facilities, schedules and manpower. The Development Engineering Group directs the integrated test program. Experimental Engineers from the Project groups define each test to be conducted, the instrumentation required, the facilities to be employed, the data to be recorded, etc., and personally direct each test. Integration of the test program is a continuous process and is accomplished through the procedures detailed herein and the close interrelation of the Assistant Project Engineers and Project Engineers within the Development Group and those responsible for the program disciplines within the Product Assurance Group. Each upward level of technical direction has a wider sphere of responsibility over the detail parts, components, subassemblies, assemblies and systems that in total make up the engine.

The development testing is divided into four general categories:

1. Where a multiple choice exists or design data are required, design selection tests are run
2. Verification tests are run to confirm that the designs of the subsystems have met their design goals
3. Reliability tests are conducted to assure that the engine and its subsystems meet the reliability goals for the SST
4. Integrated into this development test program are the test requirements of the disciplines such as Safety, Maintainability, Human Engineering, Value Engineering, and Quality Assurance.

Figure 2 illustrates the types of full-scale engine tests required to meet the objectives of the JTF17 development program. A complete description of the tests, schedules, facilities used, and evaluation of data for full-scale engines and rigs is given in Volume III, Report E.

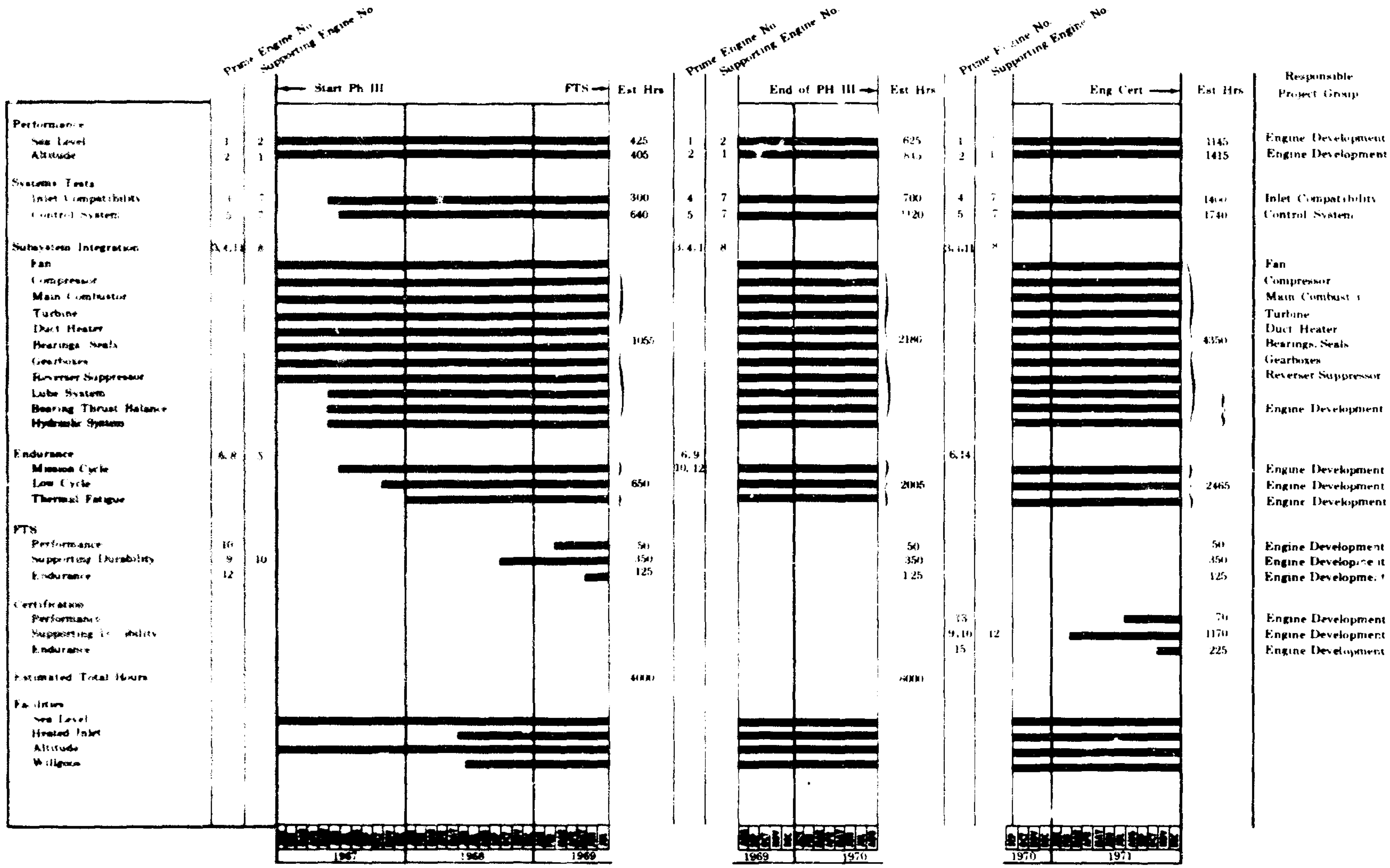


Figure 2. Types of Full-Scale Engine Tests Required to Meet JTF17 Development Program Objectives

FD 17752
EI

To assist in the integration of the testing, statistical methods hav been applied during the pretest planning. Component and engine test programs are devised to obtain the maximum relevant information from each test by (1) proper design of the experiment, (2) analysis of instrumentation precision and accuracy, (3) statistical data analysis, and (4) the measurement of the uncertainty associated with the conclusions based on the test data. Statistical methods are also used for forecasting facilities requirements, optimizing computer data reduction programs, determining instrumentation requirements and calibration methods, and in the analysis of reliability data.

For example, statistical design techniques have been used to establish the test program for the evaluation of the effect of several variables upon JTF17 ejector nozzle performance. Other statistical analyses used in the engine development program include as examples:

1. The investigation of the precision of a variety of methods of estimating burner efficiency and selection of the best method. Similar analyses have been performed for other performance parameters to select the optimum method of measurement
2. Control signal utilization schemes have been analyzed to determine factors of reliability, precision, and accuracy.

Experience has proved that complete, full-scale engine testing is the ultimate method for evaluating overall engine reliability and performance. However, it must be preceded and supported by a carefully integrated, well planned and rigorously implemented component development program. Such an integrated component and engine development program will assure the performance and reliability required for commercial operation of the JTF17 engine on schedule and for minimum cost.

As the full-scale engine test program progresses, a continuing component program is essential for evaluating modifications. Since the component test rigs are relatively inexpensive to operate and more readily available for test, it is possible to test several different configurations in a rig within the same amount of time it would normally take to test one configuration in the complete engine. In this way, modifications to component design suggested by engine test results can be easily and quickly previewed to determine changes worthwhile for testing in a complete engine. This process of component and engine testing is continued throughout the development program, not only to correct problem areas, it is also necessary to provide a base for the essential growth of a commercial airline engine.

There are numerous other requirements for rig testing that come under the category of validity testing. For these tests, rigs are employed primarily for economic and safety reasons because a failure of certain test parts in a full-scale engine could result in an unnecessarily expensive test.

Burst testing of compressor and turbine disks cannot be conducted economically in a complete engine. Another category of component testing involves structural stress evaluation of prime engine structures, which could be accomplished only by subjecting an engine to violent aircraft maneuvers. Reliability tests involving very high numbers of stress or thermal fatigue cycles would represent thousands of hours of engine testing, but can be readily accomplished on rigs in a much shorter period of time.

The component test program is coordinated with the complete engine program by the Manager, JTF17 Development, who directs the Project Engineers responsible for the data analysis, redesigns, procurement and testing of the engine components and full-scale engines. The Manager, JTF17 Development, is responsible for meeting program development schedules and requirements.

2. Integration Plan

a. Development Program Control

The Manager, JTF17 Development, will control the overall development program utilizing as a primary tool the Management Network for the integrated test program. A graphic presentation of this Level 3 network is shown in figure 3. The computerized program upon which this network is based includes a detailed program beyond Level 3 which will be fully implemented by the beginning of Phase III. The outputs of this program will serve as the primary display of the Integrated Test Plan during Phase III.

As a part of the reporting system for monitoring development program progress, the Manager, JTF17 Development, will receive a tabulated semimonthly status report from the PREDICT (Programed Engine Development Integration Control Technique) system, which will include summary-type information for each test completed, in progress, or planned. Planned tests will be programed for the complete development program. Particular attention will be directed at the next 30-day period. The semimonthly tabulation will display the development program revisions and added tests required as a result of development test successes and failures. Inputs to the test program revisions or additions will be supplied by the Project Engineers based on requirements furnished by Design, Performance and the various Product Assurance disciplines.

The PREDICT tabulated status report will include the following information:

- Test type
- Status of the test (completed, in process, etc.)
- Results of test (success or failure)
- Test report/corrective action
- Slack time reports
- Approach warning system for tests due to be conducted within 30 days
- Additions and/or changes to the plan

FIGURE 3, TEST PLANNING AND INTEGRATION,
ACCOMPANIES THIS PROPOSAL
AS AN ADDENDUM TO
VOLUME IV

A sample tabulation is shown in Exhibit "A" of the Appendix to this report. Individual work statement items are described in the following paragraphs.

b. Design

The integrated test plan for the design effort is shown in a network chart (Engine Design) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section I. The design effort for the engine test program is the refinement of the JTF17 design completed in Phase II-C and supporting effort for the development program. This effort includes the establishment of the Parts List as the development program continues.

c. Fabrication and Assembly

The integrated plan for fabrication and assembly of the twelve engines utilized in Phase III is shown in a network chart (Fabrication and Assembly) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section I. Fabrication of the twelve sets of parts for initial build of the engines as well as supporting hardware for the engines, is described in detail in the Manufacturing Program, Volume V, Report G.

d. Test Equipment

The integrated plan for test facilities is shown in network charts (Facilities Plan) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section I. The integration of the test programs, component and engine, with the facilities involved is illustrated in figure 3 and the detail networks for each component included in the Detail Work Plan.

e. Component Test Plan

(1) Fan and Compressor

The integrated test plan for the fan and compressor development is shown in a network chart (Fan and Compressor) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section II. Testing in Phase III will be done on the 0.6-scale fan rig until the full-scale fan rigs become active in the program. Design selection and verification tests will be conducted on these rigs with inlet distortion and noise tests being integrated into the program. The high compressor rig available from Phase II-C will continue to be tested and additional full-scale rigs will be added to the program. Full-scale engine testing will be evaluated for conformance to design goals. A continuous cycle of evaluation, redesign and test will be carried out until design goals have been met.

(2) Primary Combustor

The integrated test plan for the primary combustor development is shown in a network chart (Primary Combustor) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section II. Design

selection testing will continue on the 30- and 120-degree segment rigs available from Phase II-C, and verification tests will be conducted on the full-scale annular combustor in the JT4 engine. As soon as the JTF17 high spool rig is available, primary combustor tests will be combined with high turbine testing in this rig. Data from these rigs and full-scale engine testing will be evaluated for conformance to design goals. A continuous cycle of evaluation, redesign, and test will be carried out until design goals are met.

(3) Turbine

The integrated test plan for turbine development is shown in a network chart (Turbine) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section II. Design selection testing will continue on the thermodynamic and aerodynamic rigs available from the Phase II-C program. A static cascade thermal fatigue rig and a high spool rig consisting of the high compressor, primary combustor, and turbine of the JTF17 engine will be designed and procured. The high spool rig will be used to investigate interactions of the main combustor and turbine as well as verification testing. Blade and vane configurations that show promising results in the design selection tests conducted on thermodynamic and aerodynamic rigs will be verification-tested in the static thermal fatigue rigs. Concurrent and supplemental verification testing will be conducted in the high spool rig, which more closely simulates full-scale engine conditions. Data from these rigs and full-scale engine tests will be evaluated for conformance to design goals. A continuous cycle of evaluation, redesign and test will be carried out until design goals have been met.

(4) Augmentor

The integrated test plan for the augmentor is shown in a network chart (Augmentor) in the Detail Work Plan, Volume V, Report H and is described in Volume III, Report E, Section II. Design selection and verification testing will continue on the sector rigs, and full-scale annular rig and the 0.62-scale diffuser rig utilized in Phase II-C after minor modifications are made to update the rigs. Selection tests will be conducted on water tunnel rigs for flow visualization and spraybar benches to refine configurations. In addition to verification tests, reliability and functional tests such as relights on full-scale engines will be conducted and evaluated, redesigns will be evolved and tested until design goals are met.

(5) Exhaust System

The integrated test plan for the exhaust system is shown in a network chart (Exhaust System) in the Detailed Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section II. Model tests will continue for both performance and installation effects. Subsystems of the exhaust system such as the clamshells and tailfeathers will undergo rig design selection testing for durability as affected by wear, thermal loads, acoustics and contamination. Full-scale verification testing of the exhaust system will be conducted on engines and will include durability, noise, and performance in forward and reverse thrust modes of operation. These data will be evaluated and redesigns evolved as required until design goals are met.

(6) Controls and Accessories

The integrated test plan for the controls and accessories of the JTF17 engine is shown in a network chart (Controls and Accessories) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section II. Design selection and verification tests will continue on the components available from the Phase II-C program and will continue to be used until the JTF17 integrated fuel control system is available. Digital computer and analog work will continue throughout Phase III including a complete analog simulator of the engine-inlet control system. A failure mode and effect analysis will be conducted as a part of the program. Data from this program and full-scale engine verification testing will be evaluated, redesigns will be evolved as required and tested until goals are met.

(7) Bearings, Seals and Gears

The integrated test plan for bearings, seals and gears is shown in a network chart (Bearings, Seals and Gears) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section II. Environmental design selection testing of the bearings and seal compartments will continue utilizing rigs available from Phase II-C. Designs will be produced as required to update them to the current JTF17 Parts Lists. Design selection and reliability tests will be conducted on those configurations which show promise. Reliability testing on the bearings will include oil starvation and B-10 life tests. Testing of the JTF17 gearbox system will be conducted at environmental conditions and accomplished on a rig which consists of the complete gearbox and lubrication system of the JTF17 engine. Design selection and verification testing will be conducted followed by durability and reliability testing. Data from these rigs and full-scale engine testing will be evaluated for conformance to design goals. Redesigns will be evolved as required and tested until design goals are met.

(8) Fuel

The integrated test plan for fuel development is shown in a network chart (Fuels) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report E, Section II. Candidate fuels will continue to be evaluated in laboratory tests including coker tests, for lubricity and conformance to fuel specifications. Close coordination will be maintained with the airframe contractor, operating airlines, and fuel companies during Phase III. Compatibility of the fuel with engine components such as the hydraulic pump and main fuel pumps will be conducted in bench tests at environmental conditions. The effects of hot fuel on fuel nozzles will be evaluated in rig tests and in full-scale engine testing. A full-scale engine test with the airframe fuel system will be conducted during Phase III. The fuel specified for the JTF17 engine will be determined by these tests.

(9) Lubricant

The integrated test plan for the development of lubricants is shown in a network chart (Lubricants, and Lubrication System) in the Detail Work Plan and is described in Volume III, Report E, Section II. Candidate lubricants will be tested in conjunction with the bearing seal, and gearbox

tests described in Subparagraph (7). In addition to these tests, ERDCO bearing tests will be conducted. These rig tests and full-scale engine tests will be used to develop the lubricant specified for the JTF17 engine.

f. Full-Scale Engine Test Plan

The integrated test plan for the JTF17 engine is shown in figure 2 of this report and a network chart (Test Planning and Integration) in the Detail Work Plan, Volume V, Report H, and is described in detail in Volume III, Report E, Sections III, IV, V, and VI.

(1) Overall Test Program

As shown in Volume III, Report E, complete full-scale engine testing provides the final verification that required reliability, performance and operating characteristics have been achieved.

Design selection and preliminary verification tests are run on all engine components prior to the selection of the best configurations for test in the complete full-scale engine. These component tests include performance and structural tests and must include interaction of subsystems. Thus, high compressor rig testing is conducted with fan discharge profiles; duct heater soft light effects are checked on the fan rig, and inlet distortion effects are determined on individual fan and compressor rigs. As soon as sufficient confidence is obtained in a component configuration, it is released to full-scale engine testing for verification of the rig test results and to conduct durability and subsystem integration tests.

Initial engine testing occurs at sea level static conditions and has as its object overall engine performance, component performance, and verification of systems design such as thrust balance, oil systems, and control systems. The engine configuration is continually updated by design changes resulting from the component program as well as the full-scale engine program. As confidence is obtained in the full-scale engine configuration, durability testing is conducted at sea level and at simulated flight conditions. Initially short periods of endurance are run with frequent inspections of the engine including pretest inspections, interim inspections on the occasion of shutdown for routine maintenance, hot section inspections and complete teardown inspections. The object of the endurance testing is to demonstrate durability of the engine, obtain engine and component performance data, verify system design, and verify fuel control scheduling for both main and duct heater control systems. During testing at simulated flight conditions, functional characteristic testing such as duct heater relight envelope, main combustor relight envelope and windmill performance is integrated into the endurance program. The test requirements of the program disciplines such as maintainability, human engineering, reliability, safety, etc., are integrated into all phases of the test program. Quality Assurance standards, established on engine parts prior to manufacturing, are upgraded as the engine test results indicate a need. Maintainability estimates are verified at engine assembly and at test during the routine engine inspections and part changes that occur as a normal part of a development program.

Prior to conducting the FTS test the JTF17 engine will complete the following tests:

1. Performance demonstration at sea level and altitude
2. Overspeed spin tests on representative disks
3. Containment
4. Low cycle fatigue
5. Thermal fatigue tests in the high spool rig
6. Aerodynamic brake actuation tests
7. Company FTS endurance

These tests are described in detail in Volume III, Report E, Section IV.

After completion of the FTS test, a continuing program of engine development will be conducted with emphasis on support of the 100 hour flight test program at the airframe contractor. The flight test plan is more fully described in Subparagraph g. The development program following FTS is planned such that an uninterrupted continuation with timely and adequate funding will lead to engine certification. The test program is described in detail in Volume III, Report E, Section VI. The description of the test program beyond Phase III is limited to the proposed Certification Program. The recommended tests are as follows:

150-hour engine and reverser-suppressor endurance
Performance demonstration at sea level and alitutde
625-hour mission cycle test
500 cycles of low cycle fatigue testing
1000 cycles of thermal fatigue testing
Maximum low and high rotor speed endurance
Maximum exhaust gas temperature endurance
Overtemperature test
Aerodynamic brake actuation tests
Foreign object ingestion tests
Engine inlet icing tests
Disk overspeed tests
150-hour gearbox endurance
Rotor stress demonstration
Blade containment
Oil tank pressure tests.

(2) Engine-Inlet Compatibility Plan

Engine-inlet compatibility is a major consideration in the development program of the JTF17 engine. The Engine-Inlet Compatibility Plan incorporated in the integrated test plan encompasses rig testing, development engine testing at P&WA, and delivery engine testing by the airframe contractor. The test plan is shown in a network chart (Inlet System Compatibility) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report D, Section II. Distortion testing begins early in Phase III on the 0.6-scale fan rig to provide design selection information as early as possible in the program. Distortion testing on full-scale engines will also begin early in Phase III utilizing one of the Phase II-C engines. This engine will incorporate a prototype fan and will use a distortion generator. Results from testing this engine will be used to

verify the result from fan rig testing. Verification tests will be conducted on a JTF17 Phase III engine with distortion generators and a simulated inlet at sea level and typical flight conditions. Data from these tests are evaluated and redesigns evolved and tested until design goals are met. Close coordination will be maintained with the airframe contractor throughout the program so that realistic distortion values are used in this testing. The configuration determined by these P&WA tests will be incorporated in the JTF17 parts list including the delivery engine that will be used for the AEDC engine-inlet compatibility test and tests at the airframe contractor test site.

During Phase II-C, the following activities related to the flight test program have been achieved. A complete description of these activities is contained in Volume III, Report D, Section II, Engine-Inlet System Compatibility.

1. Analog and/or digital simulations of the engine-inlet systems have been exchanged, and updated as required, between Pratt & Whitney Aircraft and the airframe contractors.
2. Inlet distortion data obtained from model tests for a variety of flight conditions have been received from the airframe contractors and reviewed with respect to compatibility with the JTF17 engine.
3. Coordination of an engine-inlet compatibility test program, to be conducted at AEDC, has been completed with both candidate airframe contractors. This program will be updated as required in Phase III.
4. A computerized analytical method to predict transient distortion characteristics of the fan and compressor has been started.

(3) Noise

The integrated test plan for noise suppression is shown in a network chart (Noise) in the Detail Work Plan, Volume V, Report H, and is described in Volume III, Report C. The Phase III program is a continuation and expansion of the Phase II-C program and encompasses model testing, rig testing and full-scale engine testing. Design selection tests are conducted on model testing for nozzle geometry and exhaust noise suppression devices. Design selection and verification testing will be conducted on the fan rigs and shall include vane angle effects, stage pressure loading effects, rotor-to-stator spacing effects, and vane number effects. Acoustical liner effects will be evaluated in full-scale engine testing. Verification testing of the designs selected for the JTF17 engine will be conducted on full-scale engines. Data from these tests will be evaluated, and redesigns will be evolved and tested until design goals are met.

g. Flight Test Plan

(1) Goal

The flight test program to be initiated in Phase III is directed toward demonstration of the capability of the SST to accomplish its basic missions. A more detailed description of the Flight Test Program is contained in Volume III, Report E, Section V.

(2) Flight Test Support

The following Phase III Program effort is directed toward this goal.

1. Prepare, implement and maintain a Flight Test Program in conjunction with the airframe contractor.
2. Demonstrate suitability of the prototype JTF17 engine for flight test by successful completion of the FTS.
3. Deliver Ground, Taxi, and Prototype JTF17 engines.
4. Provide adequate engineering and product support coverage at all test sites during all phases of the flight test program. This effort is described in detail in Report F, Section VI, Product Support.
5. Conduct a continuing development program in support of the flight test.

During Phase II-C, agreements have been negotiated with the airframe contractors setting forth the understanding of the parties with respect to their responsibilities in supporting the Flight Test Program. These agreements are provided in the airframe contractors' proposal.

(3) Flight Test Programs

The following test programs will be coordinated with the airframe contractor for incorporation into the 100-hour flight test program:

- Ground Tests
  - Uninstalled
    - Performance
    - Compatibility with inlet and accessories
  - Installed
    - Starting
    - Thrust response
    - Performance
    - Vibratory characteristics
    - Reverse thrust
    - Noise
    - Distortion
    - Nacelle environment
    - Maintainability

- Taxi Tests
  - Reverse thrust response and adequacy
  - Foreign object ingestion susceptibility
- Flight Tests
  - Performance
  - Windmill
  - Vibratory characteristics
  - Inlet profile distortion
  - Relight of main combustor and duct heater
  - Nacelle environment
- Oil System Tests
  - Heat rejection
  - Oil consumption
  - Engine breather flow and pressures
  - Main oil pump performance
  - Scavenge oil system performance
  - Control system tests, steady-state and transient conditions.

h. Delivery Engines

The delivery engines will be calibrated and instrumented. A proposed delivery schedule of instrumented and calibrated engines is included in figure 4. Engines that are designated as Instrumented Engines will incorporate the items shown in figure 5 and will incorporate additional instrumentation provisions in the form of "kit" parts that can be supplied with the engine. The instrumentation provisions will be coordinated with the airframe contractor.

Engines that are designated Calibrated Engines will undergo a calibration test at Pratt & Whitney Aircraft, consisting of a series of steady-state points from idle to maximum augmented thrust in approximately equal thrust increments. The details of the calibration program, as well as special calibration testing, will be mutually agreed upon by Pratt & Whitney Aircraft and the airframe contractor in accordance with the Airframe/Engine Compatibility Agreements negotiated with the airframe contractors. Test data will be supplied to the airframe contractor.

i. Program in Support of Flight Test Program

The following test program will be conducted in support of the 100-hour Flight Test Program. Where applicable, the program will be coordinated with the airframe contractor and a constant interchange of data will be maintained.

Data obtained from the flight test program and continued development engine testing will provide the basis for initiating any required corrective action. Flight test failures or deficiencies will initiate corrective action in a manner similar to a failure or deficiency noted in the development program. The procedures are described in Paragraph E.

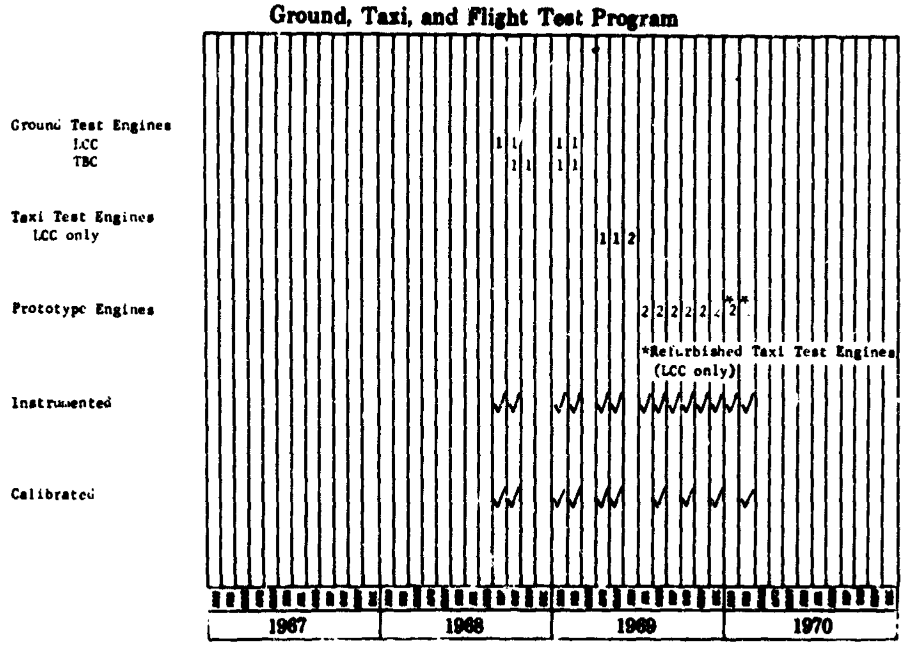


Figure 4. Engine Delivery Schedule

FD 16798
EI

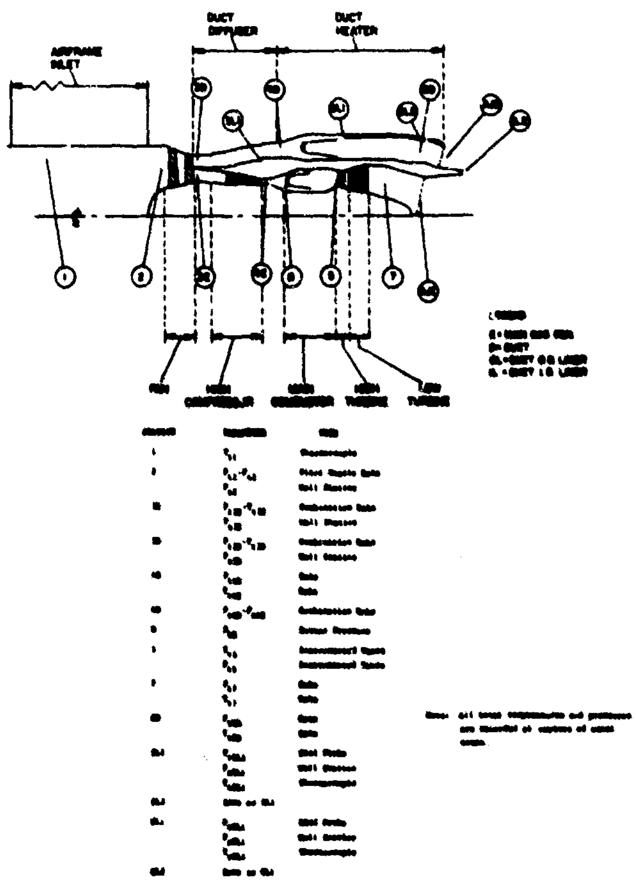


Figure 5. JTF17 Engine Instrumentation

FD 16799
EI

The following test programs are common to the engine development cycle prior to delivery of the engines, to the corrective action cycle prior to delivery of the engines, and to the corrective action cycle for problems encountered in the Flight Test Program.

- Fan rig distortion tests
- Full-scale engine distortion tests
- Engine-Inlet compatibility tests
- Airframe component engine interface compatibility tests
- Company endurance tests

All engine parts incorporating changes and provided for retrofit of flight test engines will be subjected to the FTS endurance test or its equivalent as appropriate.

j. Data Flow

The data obtained from the Flight Test Program will be evaluated by Pratt & Whitney Aircraft in cooperation with the airframe contractor. Data flow and procedures, which will be coordinated with the airframe contractor in Phase III, are described in more detail in Report F, Section VI Product Support.

E. DEVELOPMENT PROGRAM CONTROL AND PROCEDURES

The development program flow chart including approval loops and corrective action loops are shown in figure 6. The following is a general description of the procedures.

1. Program Initiation

The Program Manager initiates program activity by an Engineering Order (EO) (Exhibit B, Appendix) that authorizes work on the program. The EO is approved by the JTF17 Program Manager, Engineering Manager, and the FRDC General Manager.

2. Definition of Requirements

The broad requirements are defined in initial Engineering Order Supplements (EOS) (Exhibit C) prepared by the Manager, JTF17 Development and approved by the Program Manager. When the estimated cost exceeds $1000, the specific requirements for each component and subsystem of the engine, including design, fabrication, assembly, test, scheduling, evaluating data and reporting requirements are defined by additional Engineering Order Supplements prepared by the Project Engineers and Assistant Project Engineers, and approved by the Manager JTF17 Development.

3. Design Phase

The designs evolved from the requirements of the Engineering Order Supplements are reviewed and approved in the layout stage in accordance

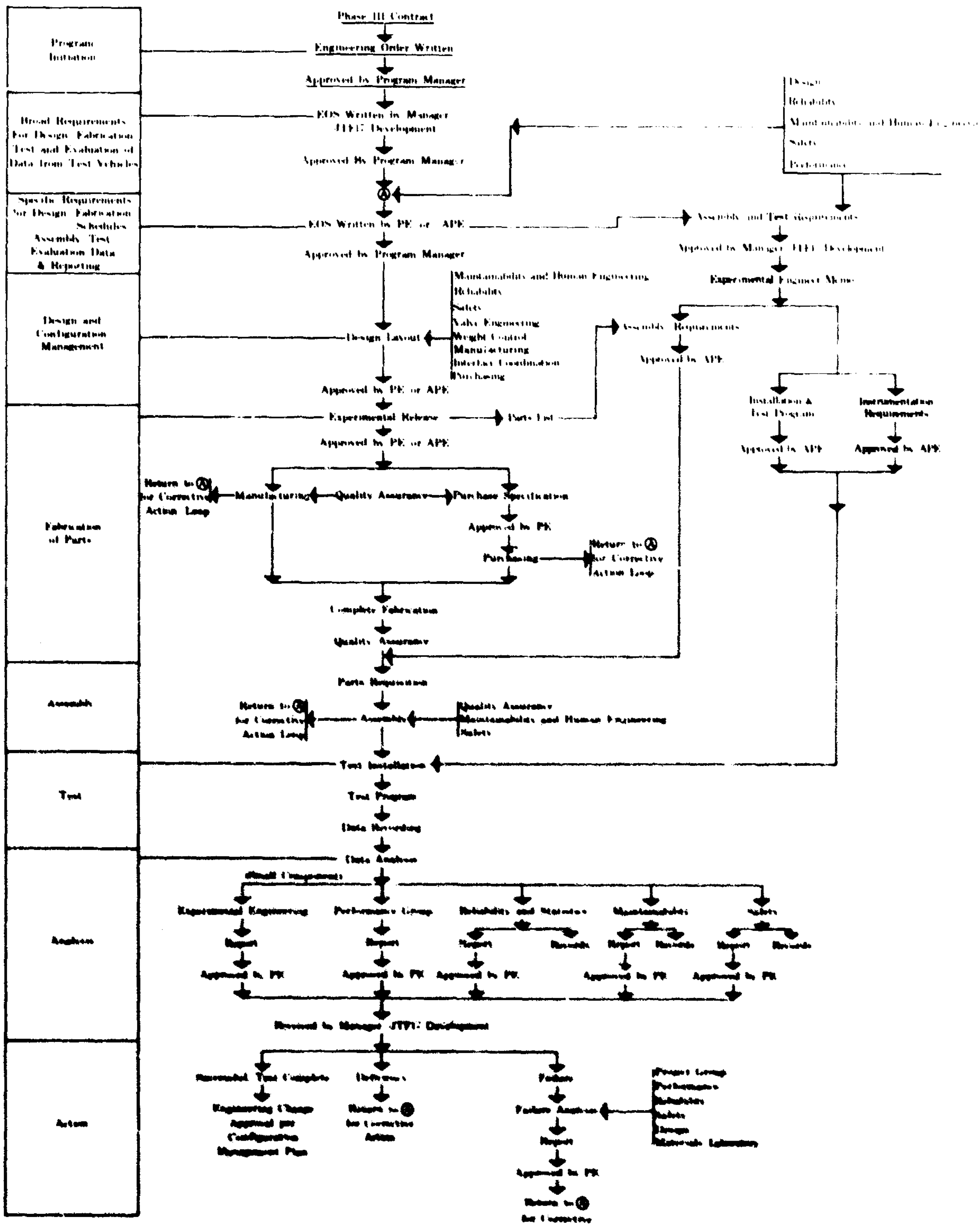


Figure 6. JTF17 Development Program Flow Chart FD 17753 EI

with the procedures of the Configuration Management Plan. In addition to all program discipline requirements such as Maintainability, Reliability, Safety, and Value Engineering, Manufacturing and Purchasing have a monitoring and advisory function at this stage to ensure producibility of the design. The design layouts are finally approved by the Project Engineer or Assistant Project Engineer originating the work. Detail drawings are prepared by Design and approved by the Project Engineer or Assistant Project Engineer.

4. Fabrication

The Project Engineer or Assistant Project Engineer releases the design for fabrication by an Experimental Release (Exhibit C). Parts may be fabricated in-house or by vendors depending upon the nature of the part and/or the in-house capacity. This make-or-buy decision is made by specialists within the Manufacturing Department in accordance with policies and directives established by the Source Selection Board.

Parts that are purchased are submitted for competitive bids by the Purchasing Department. The parts are accompanied by a Purchase Specification that defines the special requirements of the part, functional tests to be performed before acceptance of the part, quality control standards to be met, etc. This Purchase Specification is approved by the responsible Project Engineer. Where specific manufacturing talents are required that are either proprietary to the vendor or do not lend themselves to normal inspection procedures (such as a proprietary casting technique for turbine blades) a Source Approval Sheet (Exhibit D) is issued by Design and approved by the responsible Project Engineer. This document restricts the sources of this part to those specified on the document. In all phases of procurement and fabrication, Quality Assurance inspections and controls are implemented to ensure that all parts meet the quality requirements.

All parts being fabricated are monitored by a Project Materials Control Group and weekly reports (Exhibit E) are submitted to the Manager, JTF17 Development, on the status of the parts.

As drawings are released, Experimental Engineers from the Project Group concerned are assigned to follow the progress of the parts through the process of experimental manufacturing. Quality Assurance specifies control and inspection requirements. The Experimental Engineer is responsible for assuring that these requirements have been complied with and reports his findings to the Project Group. The same Experimental Engineer follows the progress of the rig or engine parts through build in experimental assembly, test, teardown, inspection and data analysis. The Experimental Engineer thus has a unique opportunity to judge the results of design and manufacture on engine performance and reliability. Rapid feedback of information from all phases of the engine development with maximum continuity of effort is maintained by this close follow-up. Project Engineers and Assistant Project Engineers coordinating the efforts of their assigned experimental engineers can react quickly to test results and institute changes in design, material, manufacturing methods, or assembly methods as required.

5. Test Requirements

The test requirements for the program are defined by the Manager JTF17 Development and are further delineated by the Project Engineers and the Assistant Project Engineers to Experimental Engineers who direct the test programs. The successive levels of Project Engineering within the Development Group are shown in figure 1. The Assistant Project Engineer responsible for the turbine development integrates the test plan of his individual rigs and engines. The Project Engineer responsible for Engine Development, Main Combustor, and Turbine integrates the test plan of the Main Combustor, Turbine, and Engine Development Groups. The Manager, JTF17 Development integrates the test plan of the Main Combustor, Turbine, and Engine Development Group with the test plans of other project groups. Thus, the integration of the individual programs into the overall program is the responsibility of each successive higher level of the development group with the overall responsibility resting with the Manager, JTF17 Development. His integrated test plan is approved by the Program Manager.

The individual test programs are prepared by the Experimental Engineers from requirements received by memorandum from Design, Performance and the various Product Assurance disciplines and are approved by the Project Engineer or Assistant Project Engineer. The test program includes instructions for assembly of the engine or rig, instrumentation requirements, and the test program. A sample of the assembly instructions for a heat transfer test on a first turbine blade are shown in Exhibit F, and the installation, instrumentation and running instructions are shown in Exhibit G. Typical test plans for a full-scale engine test are shown in Exhibits H, I, and J.

6. Analysis and Action

The test results are returned to Project Engineering for analysis and evaluation as indicated by figure 6. A typical test report from a heat transfer test is shown in Exhibit K.

All engine and component testing requires data recording, with most engine and major component tests utilizing automatic data recording. Automatic data recording sheets and test stand log sheets are transmitted to the Performance Group for performance analysis. The results of the performance analysis are presented to Project Engineering by memorandums accompanied by curves. Minor component test data, such as the heat transfer test described previously, may bypass this portion of the flowpath with the test data transmitted directly to Project Engineering. Exhibit L contains sample pages from a 150-hour endurance test on a turbine in a full-scale engine. The full report, PWA FR-1382, is available upon request. These data are analyzed by the Project Group to determine if performance of mechanical deficiencies exist. If a deficiency exists, a comprehensive analysis is conducted to determine corrective action. Corrective action is initiated by an Engineering Order Supplement written by the cognizant Assistant Project Engineer and approved by the Manager, JTF17 Development. In the event that a failure occurs, a comprehensive failure analysis is conducted. This analysis is conducted by members of the Project, Performance, Reliability, and Safety Groups of Design, and of the Materials Laboratory. Corrective action is handled in the same manner as a deficiency discrepancy.

Weekly project meetings are held by the Manager, JTF17 Development, attended by Project Engineers, Assistant Project Engineers, and key Experimental Engineers, and representatives of those service groups associated with the current phase of the project development, to maintain flow of information, to keep overall objectives before the group, and to obtain cross-fertilization of ideas.

The Program Management System used at Pratt & Whitney Aircraft places primary responsibility for all development test programs in the hands of the various Project Groups. Figure 2 indicates the Project Group with prime responsibility for each test program. Wherever possible, multiple programs are conducted on a single test rig or engine for a given build. In these instances, the prime responsibility remains with the Project Group with cognizance over the engine or rig with secondary responsibility assigned to the Project Group with cognizance over the secondary program. For example, engine No. 1 (see figure 2) is assigned to sea level performance with prime responsibility for the test program resting with the engine development group. This test, with minor changes, is applicable to the control system of the engine. The appropriate changes are made to the test program and the tests are run concurrently. In this instance the Project Control Group has a supporting responsibility. A responsibility matrix showing primary and supporting responsibilities for all program phases and management systems is shown in table 1.

F. PROGRESS REPORTS

The Manager, JTF17 Development, receives written progress reports from the various departments concerned with the JTF17 program. These reports include daily status reports from the Project Group, weekly status reports from Design and Project Material Control, and monthly reports from all disciplines such as Weight Control, Maintainability, Reliability, and Safety. These latter reports are also submitted at appropriate intervals shorter than one month when required by special considerations or critical development problems. Exhibit M is a sample of the daily status report from the Project Group, Exhibit E is a sample progress report from Project Materials Control. In addition to the JTF17 progress reports, the Manager, JTF17 Development, receives progress reports from all Pratt & Whitney Aircraft development projects and research groups so that a crossflow of related technology is maintained at all times during the development program of the engine. Exhibit N contains sample pages from a progress report of the Special Projects - Component Group.

As described in Paragraph D2, the Manager, JTF17 Development, also receives a monthly tabulation setting forth the status of the Integrated Test Plan. The tabulation includes summary-type information for completed tests, tests in progress, and planned tests.

Table 1. Work Breakdown Structure vs Functional Responsibility

	Program Manager and Deputy Program Manager	Development Manager and Project Engineers	Fiscal Control Group	Data Management Group	Program Planning Group	Chief - Reliability	Chief - Maintainability and Human Engineering	Safety Engineer	Value Engineer	Chief - Configuration Management	Standardization Engineer	Chief Quality Assurance	Product Support Manager	Delivery Manager	Design	Performance Analysis and Statistics	Materials Laboratory	Test Operations	Manufacturing Operations	Purchasing	Flight Operations Engineers	Support Services	Spares	Installation Engineers	Field Engineers	Department Controller
Engine & Component Development																										
Engine Design	2	1	5	4	3	3	3	3	3	3	3	3	3	3	2	2	4	-	4	4	4	4	-	-	-	-
Fabrication and Assembly	2	1	5	4	3	-	3	3	3	3	3	3	-	-	3	-	3	4	2	3	-	4	-	-	-	-
Tooling	3	2	5	4	3	-	3	3	3	-	-	3	-	-	3	-	-	-	1	3	-	-	-	-	-	-
Engine Instrumentation	2	1	5	4	3	3	3	3	3	3	3	4	3	-	3	2	4	3	4	-	-	4	-	-	-	-
Test Equipment	2	1	5	4	3	4	4	4	3	-	3	-	-	-	4	4	-	2	-	-	-	-	-	-	-	-
Engine Test (Ground)	2	1	5	4	3	3	-	3	3	-	3	-	-	-	-	3	3	2	-	-	4	-	-	-	-	-
Engine Performance	2	1	5	4	-	3	-	-	3	-	-	-	-	-	3	2	-	-	-	-	4	-	-	-	-	-
Inlet System Compatibility	2	1	5	4	3	3	4	-	3	-	-	-	3	-	3	2	-	-	-	-	4	3	-	3	3	-
Noise	2	1	5	4	3	-	-	-	3	-	3	-	3	-	3	2	-	3	-	-	4	-	-	3	3	-
Growth Potential	2	1	5	4	3	4	3	3	3	-	-	-	-	-	2	2	4	-	-	-	4	-	-	4	4	-
Fan and Compressor	2	1	5	4	3	3	3	3	3	3	3	5	-	-	3	2	4	3	-	-	-	-	-	-	-	-
Primary Combustor	2	1	5	4	3	3	3	3	3	3	3	5	-	-	3	3	4	3	-	-	-	-	-	-	-	-
Turbine	2	1	5	4	3	3	3	3	3	3	3	5	-	-	3	3	4	3	-	-	-	-	-	-	-	-
Augmentor	2	1	5	4	3	3	3	3	3	3	3	5	-	-	3	3	4	3	-	-	-	-	-	-	-	-
Exhaust System	2	1	5	4	3	3	3	3	3	3	3	5	-	-	3	2	4	3	-	-	-	-	-	-	-	-
Controls and Accessories	2	1	5	4	3	3	3	3	3	3	3	5	-	-	3	2	4	3	-	-	-	-	-	-	-	-
Bearings, Seals, Gears, Lubricants	2	1	5	4	3	3	3	3	3	3	3	5	-	-	3	-	3	3	-	-	-	-	-	-	-	-
Fuel	2	1	5	4	3	-	-	3	3	-	3	5	-	-	-	-	3	3	-	-	4	-	-	-	-	-
Manufacturing and Materials	2	1	5	4	3	-	4	4	3	-	3	5	-	-	3	-	3	-	2	4	-	-	-	-	4	-
Weight Control	2	1	5	4	3	-	-	-	-	2	-	3	-	-	2	4	4	-	-	-	-	-	-	-	-	-
Management Controls and Product Assurance																										
Coordination	2	2	5	3	3	4	3	3	-	3	-	3	1	3	3	3	-	-	-	-	3	3	3	2	2	-
Maintainability and Human Engineering	2	2	5	4	3	4	1	4	4	3	4	4	2	-	3	-	-	3	3	-	3	3	-	3	3	-
Reliability	2	2	5	4	3	1	4	4	4	3	-	3	3	-	3	3	-	3	3	3	4	3	-	3	3	-
Quality Assurance	2	2	5	4	3	3	-	-	3	5	3	1	2	2	3	3	4	4	3	3	-	4	-	-	-	-
Value Engineering	2	3	5	4	3	4	-	-	1	3	4	4	-	-	3	-	4	3	3	3	-	4	-	-	-	-
Configuration Management	2	2	5	3	3	3	3	3	3	1	3	3	3	3	3	3	-	-	3	-	-	3	-	3	3	-
Safety	2	2	5	5	3	4	4	1	5	3	-	3	3	-	2	-	4	3	3	-	4	3	-	-	3	-
Test Planning and Integration	2	1	5	3	3	3	-	4	3	-	3	4	5	-	4	2	3	2	4	-	4	4	-	4	4	-
Data Management	2	2	5	1	3	-	-	-	3	3	3	3	3	3	3	3	-	-	-	-	-	3	-	3	-	3
Program Management	1	2	5	3	2	3	3	3	3	2	-	-	2	2	4	4	4	4	4	4	-	-	-	4	-	-
Facilities Plan	1	3	5	4	3	-	-	5	3	-	-	-	3	-	-	4	-	2	2	4	-	-	-	-	-	4
Cost Analysis	2	3	1	3	3	-	-	-	3	-	-	-	3	3	3	-	-	3	3	3	-	-	-	-	-	2
Proposals	1	3	3	3	3	4	4	4	4	4	-	-	3	3	3	3	4	4	3	4	-	3	3	-	-	3
Delivery and Product Support																										
Ground, Taxi, and Flight Engines	2	4	5	3	3	-	-	-	3	5	-	3	3	1	-	-	-	3	2	3	-	-	-	-	-	-
Tooling	3	-	5	-	3	-	-	-	3	-	-	3	-	2	-	-	-	-	1	3	-	-	-	-	-	-
Performance	3	3	5	-	-	-	-	-	-	-	-	5	3	1	-	3	-	-	-	-	5	5	-	5	5	-
Mockup	3	2	5	-	3	-	3	-	-	3	-	3	1	-	3	-	-	-	3	-	-	3	-	3	3	-
Spares	3	4	5	-	3	-	-	-	3	-	-	3	1	2	-	-	-	-	2	3	-	3	2	-	-	-
Overhaul	3	4	5	-	3	-	5	-	3	5	-	3	1	2	-	3	3	3	2	-	-	3	3	-	-	-
Flight Test Evaluation	3	1	5	-	3	3	-	-	-	-	-	-	3	-	3	2	-	-	-	-	4	3	-	3	3	-
Data and Handbooks	3	4	5	3	3	-	3	-	-	3	-	-	1	4	3	3	-	-	3	-	3	2	-	2	4	-
Training	3	4	5	4	3	-	3	4	-	-	-	-	1	-	-	-	-	-	-	-	3	2	-	4	3	-
Ground Support Equipment	2	3	5	-	3	4	3	4	3	3	3	3	1	-	3	-	-	4	3	3	4	2	3	4	4	-

Code:
1. Prime responsibility
2. Shared responsibility
3. Active Participation
4. Advisory function
5. Monitoring function
- Not applicable

G. FACILITIES

The facilities required for the JTF17 Development Program are described in detail in Volume III, Report E, Section I. The test stands required consists of:

- Three sea level calibration and endurance stands
- One sea level noise and reverser stand
- Three heated inlet stands
- Two high Mach number altitude stands
- One subsonic altitude stand.

As indicated by figure 3, the stand availability schedules are integrated into the test plan and will be available when required by the test program.

H. CHANGE CONTROL PROCEDURES

The control of the configuration of the development (experimental) and prototype engines and procedures for affecting engine changes is described in detail in the Configuration Management Plan, Volume V, Report C.

The design of the JTF17 engine is initiated by an Engineering Order establishing the program and a series of Engineering Order Supplements establishing the design requirements for the major engine components (Exhibit C). As the design layouts are completed part and assembly numbers are assigned to the parts and an engine parts list is started. The Engine Parts List (Exhibit C) is a machine-stored numerical listing of the parts and assemblies comprising the latest configuration of an engine model. The list can be machine-printed quickly for ready reference by Program Management personnel or for use in establishing the next build configuration of a development engine.

Changes to the Engine Parts List for the development engines or the release or revision of development engine drawings during the development phase are controlled by Experimental Releases (Exhibit C). These releases require Configuration Management approval and are then approved by the Chief Draftsman and the Manager, JTF17 Development, or his delegate.

During the development program, a preliminary Engineering Assembly Parts List Complete (Exhibit C) is originated for establishing the configuration of the prototype engine.

Changes to this preliminary engine "baseline" configuration to improve the installation, performance, reliability, cost and/or manufacturing of the engine, can be requested by (1) memorandum, (2) Engineering Order Supplement, or (3) an Engineering Change Request (Exhibit C). If the change is requested by memorandum or EOS, the JTF1 Chief Draftsman will originate the Engineering Change Request. The Engineering Change Request is forwarded to the Engineering Records Change Control Group where it is assigned an Engineering Change serial number, and returned

to the JTF17 Design Group for design analysis. Initial action on the part of Design is to evaluate the nature and reason on the Request for Change in conjunction with related problem or failure reports. The evaluation includes coordinating with the applicable Design Product Assurance and Project Engineering groups on general feasibility, and the effect on performance, weight, safety, reliability, maintainability, human engineering, cost and the airframe installation.

If new parts are indicated, the drawings are prepared and an Engineering Release initiated and approved as above so that engine parts requiring development testing may be procured.

The Engineering Change in Design (Exhibit C) is then prepared and circulated in preliminary form to the concerned departments for planning, costing and coordination purposes and approvals. The final Engineering Change including the drawing supporting and supplemental information is then forwarded to the Project Engineer and Manager, JTF17 Development, for approval. This procedure is followed during the development phase following release of the preliminary Parts List for the prototype engine.

At the appropriate time during the development program the final Parts List for the qualification test engine is determined. Satisfactory completion of the qualification test then establishes the configuration of the delivery engines. The Engineering Assembly Parts List complete for the delivery engines is then issued by an Engineering Release to Delivery Engine Manufacturing. The Engineering Release is approved by the Chief, Configuration Management and the JTF17 Development Program Managers.

Configuration changes which affect the delivery engine Engineering Assembly Parts List are accomplished only through the formal Engineering Change system.

I. PHASE II-C STATUS AS OF 1 AUGUST 1966

All major JTF17 program milestones have been achieved 2 to 3 months ahead of the predicted schedule. A comparison of the engine operating time with the Phase II-C contractural commitments is shown in the following table.

Phase II-C Contractural Requirements	Phase II-C Status
100 hours of test time	73.11 hours completed
5 hours of heated inlet time	2.07 hours completed
5 hours augmented test time	15.65 hours completed
5 hours of 2000°F or higher turbine inlet temperature time	Completed 18.38 hours at or above 2000°F

The four-bearing construction with separately balanced unitized assemblies has been exceptionally free from rotor vibration. No engine starting problems have been encountered in 61 engine starts. Smooth and rapid acceleration from light-off to idle has been accomplished with the same starter system used on the J58 engine even through the JTF17 engine has more than double the airflow and thrust of the single spool J58 engine. Sea level operation of the engine has been accomplished up to 96% of rated rotor speed with a maximum thrust level of 47,800 lb obtained. TSFC at the maximum thrust was within 10% of the predicted value. Duct heater lights have been exceptionally smooth and have been successful on every attempt. Operation of the engine at cruise environment was interrupted at 1.65 hours by failure of an unshrouded 3rd-stage compressor blade. Engine TSFC at this operating point (cruise) was within 5% of the JTF17 engine goal for the thrust achieved.

A total of 64 aerodynamic modifications have been evaluated in the high compressor rig utilizing automatic data recording systems during a total of 80.64 hours of testing. Efficiency and surge lines have progressively improved with the cruise efficiency now exceeding the JTF17 goals at the required surge margin. The efficiency goal has been attained at SLTO, however, surge margin improvement is needed. This lack of surge margin has been isolated to premature root stall. Single stage rotating cascade tests show effective corrective action is attained by recambering.

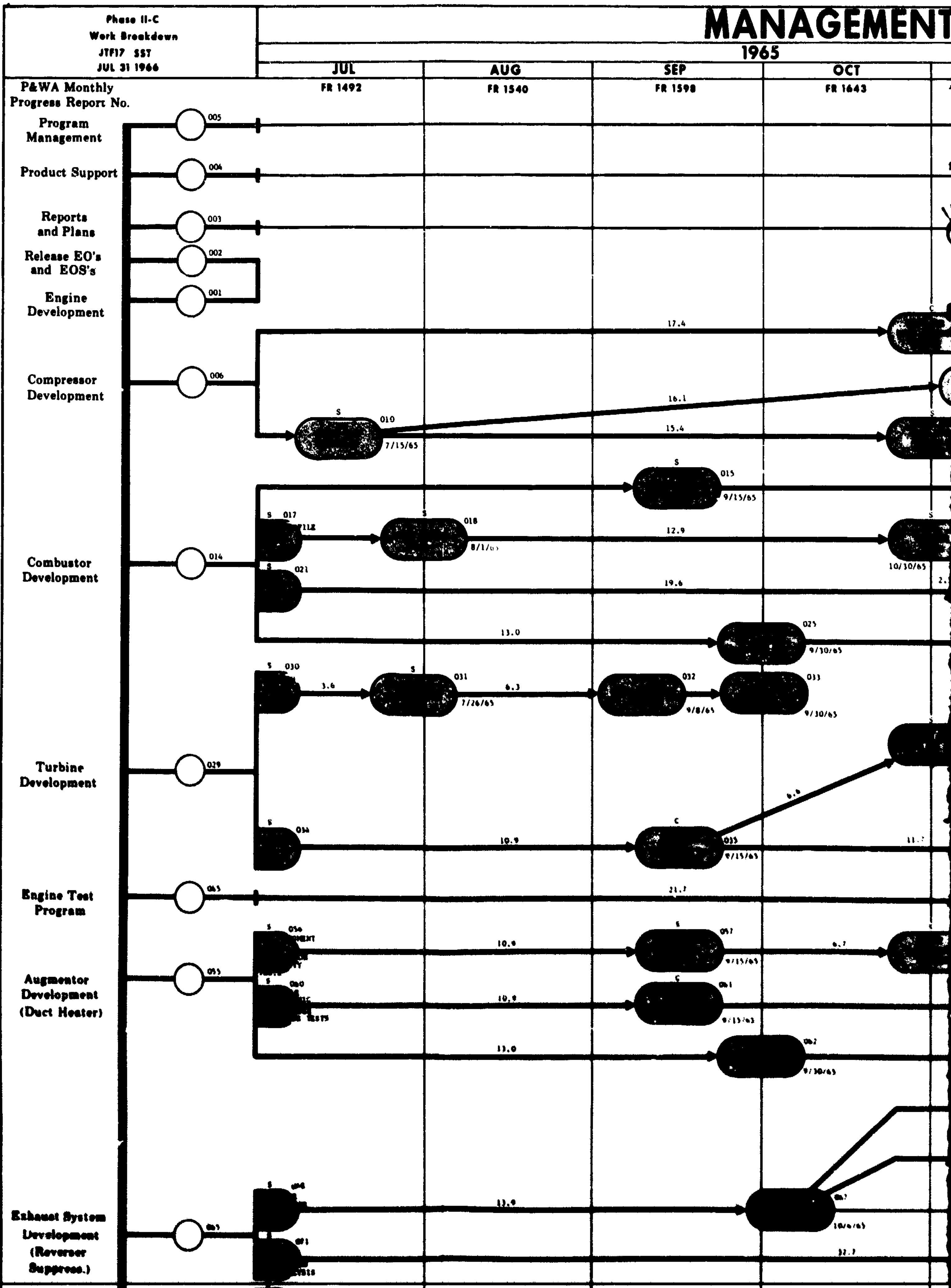
A total of 15 aerodynamic modifications have been run in the fan rig in 455.47 hours of testing. Fan airflow exceeds predictions and was instrumental in permitting the increase of engine airflow to 687 lb/sec for the JTF17A-21 rating. Improvements are required in the engine side surge line to achieve desired operating margins and an increase of 2-3% in efficiency at SLTO is needed to attain the JTF17 goals. These improvements appear readily achievable through the use of the blade root aerodynamics of the JTF14 (JT9D) fan, which has demonstrated the surge margin and efficiency needed for the JTF17 fan. Fan duct side efficiencies within 1% of the goals have been achieved at all significant flight conditions.

Primary combustor rig testing has been accomplished in combustor segments rigs and on full-scale combustors installed in a modified JT4 engine. The accumulation of 351 hours of rig testing has provided a configuration with temperature distribution at the combustor discharge comparable with that of the exceptionally durable JT4 commercial engine. Prototype and production combustion efficiency and combustor pressure loss and sea level ignition goals have been demonstrated in full-scale and segment rig tests. Consideration given in the design phase of the combustor to smoke generation has been most beneficial. Engine smoke density measurements show a reduction of approximately 50% over the JT3D and JT8D commercial turbofan engines has been achieved.

Over 497 hours of duct heater combustor testing has also been accomplished in segment rigs and in a full-scale rig with comparably successful results. Prototype engine combustion efficiency and cold and burning pressure loss goals have been demonstrated. Successful ignition has been achieved at fuel/air ratios as low as 0.001. This "soft" lighting characteristic produces a very small pressure change and has had no effect on fan stability in the 31 successful duct heater lights accomplished during engine running.

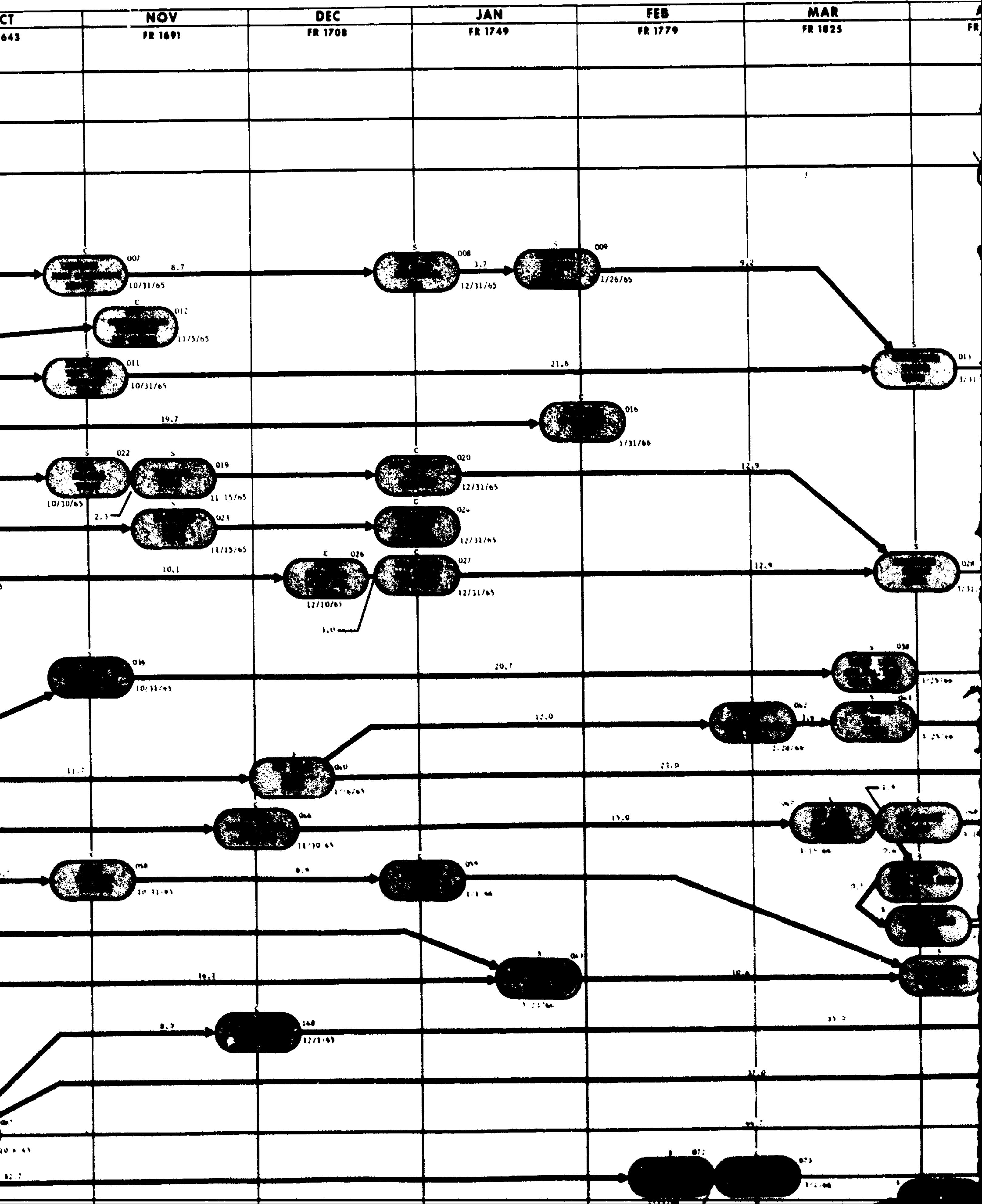
Over 655 hours of turbine blade testing in aerodynamic thermal fatigue, and heat transfer rigs and in a JT4 test vehicle were accomplished in an evaluation of various types of blade cooling arrangements. Material tests confirmed the potential of directionally solidified PWA 664 for turbine temperature or life growth and the adequacy of the well developed J58 turbine blade alloy, Inco 100, for initial production engines. Oxidation erosion testing with salt and sulphur contaminants demonstrated the rapid deterioration of all uncooled current turbine alloys, particularly U-700, and the dramatic improvement which resulted with the application of several candidate P&WA coatings. A critical assessment of a number of turbine blade cooling schemes showed the consistent superiority of a refinement of the J58 convectively cooled design with impingement cooling of the leading edge. When compared to film cooled airfoils with surface discharge of cooling air the design proved to be significantly superior in thermal fatigue tests, in aerodynamic losses and in resistance to cooling flow interruption from contaminant or foreign object damage. In addition the design was comparable in cooling effectiveness at the cooling air flows needed to maintain the desired average blade metal temperature of 1650°F.

A more complete description of the Phase II-C status is given in Volume III, Report E, Section II and III. Figure 7 shows the status of the tests for Phase II-C and indicates the Monthly Progress Report that reported the data.

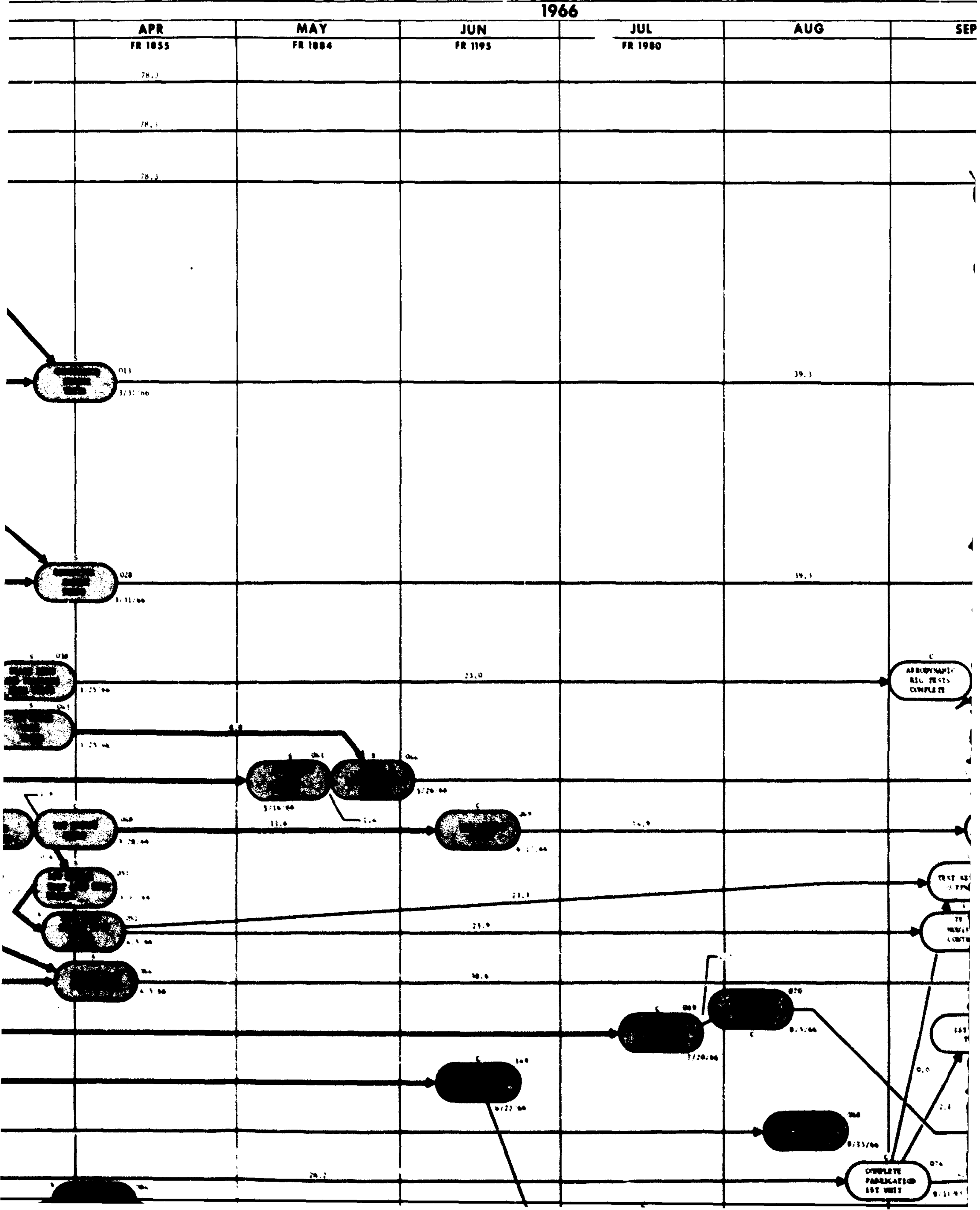

Phase II-C
Work Breakdown
JTF17 SST
JUL 31 1966
MANAGEMENT
1965
JUL
AUG
SEP
OCT
FR 1492
FR 1540
FR 1598
FR 1643
P&WA Monthly
Progress Report No.
Program Management
Product Support
Reports and Plans
Release EO's and EOS's
Engine Development
Compressor Development
Combustor Development
Turbine Development
Engine Test Program
Augmentor Development (Duct Heater)
Exhaust System Development (Reverser Suppress.)
005
004
003
002
001
006
014
029
065
055
17.4
16.1
15.4
010
7/15/65
015
9/15/65
017
018
8/1/65
12.9
10/30/65
021
19.6
13.0
025
9/30/65
030
3.6
031
7/26/65
6.3
032
9/8/65
033
9/30/65
10.9
035
9/15/65
21.7
10.9
9/15/65
10.9
9/15/65
13.0
9/30/65
13.9
10/6/65

12

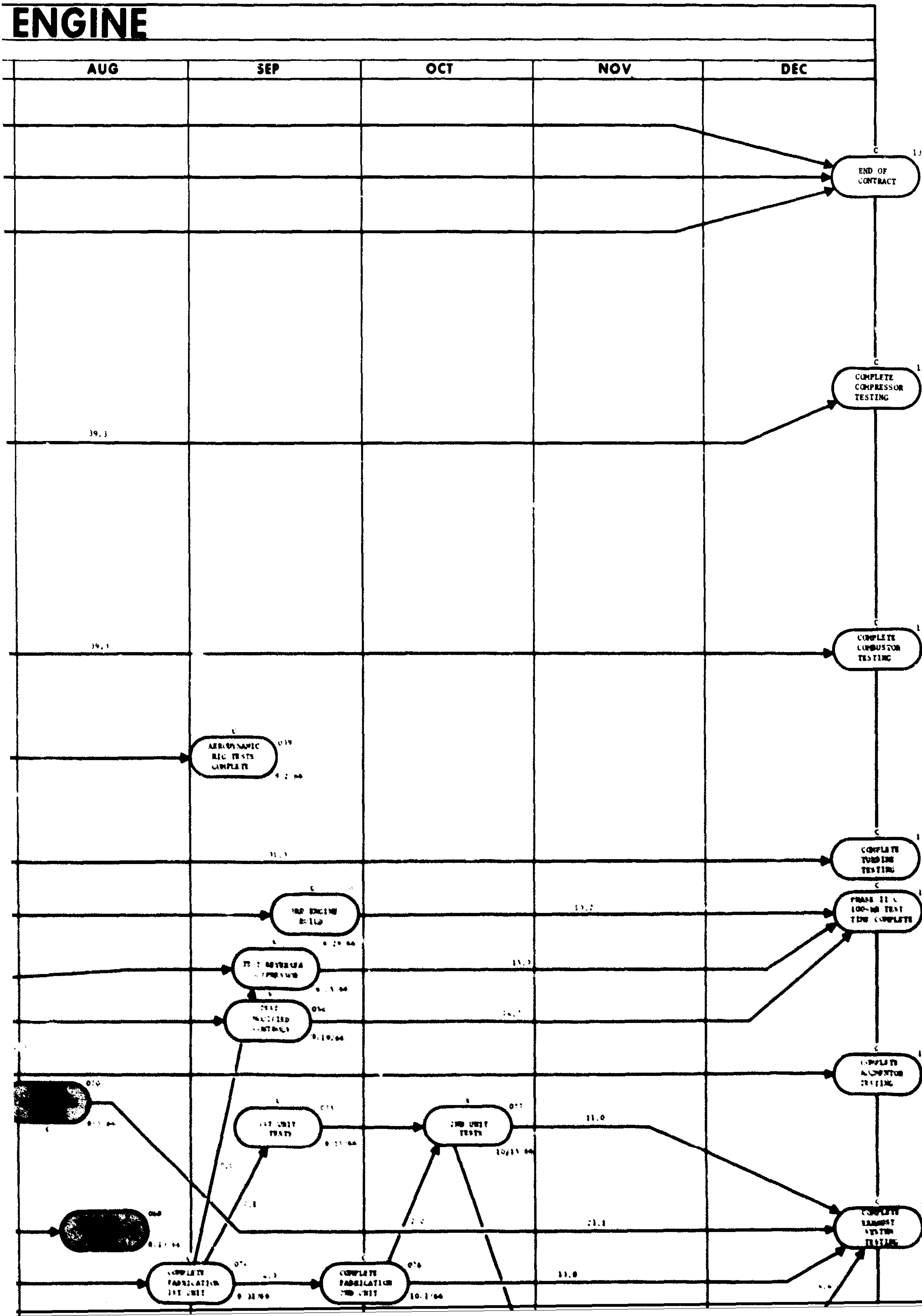
EMENT SUMMARY NETWORK DEVELOPMENT OF JTF17 SUP



TF17 SUPERSONIC TRANSPORT AIRCRAFT ENGINE



4


ENGINE
AUG
SEP
OCT
NOV
DEC
END OF CONTRACT
COMPLETE COMPRESSOR TESTING
COMPLETE COMBUSTOR TESTING
39.3
COMPLETE TURBINE TESTING
1ST UNIT TESTS
2ND UNIT TESTS
COMPLETE FABRICATION 1ST UNIT
COMPLETE FABRICATION 2ND UNIT
11.0

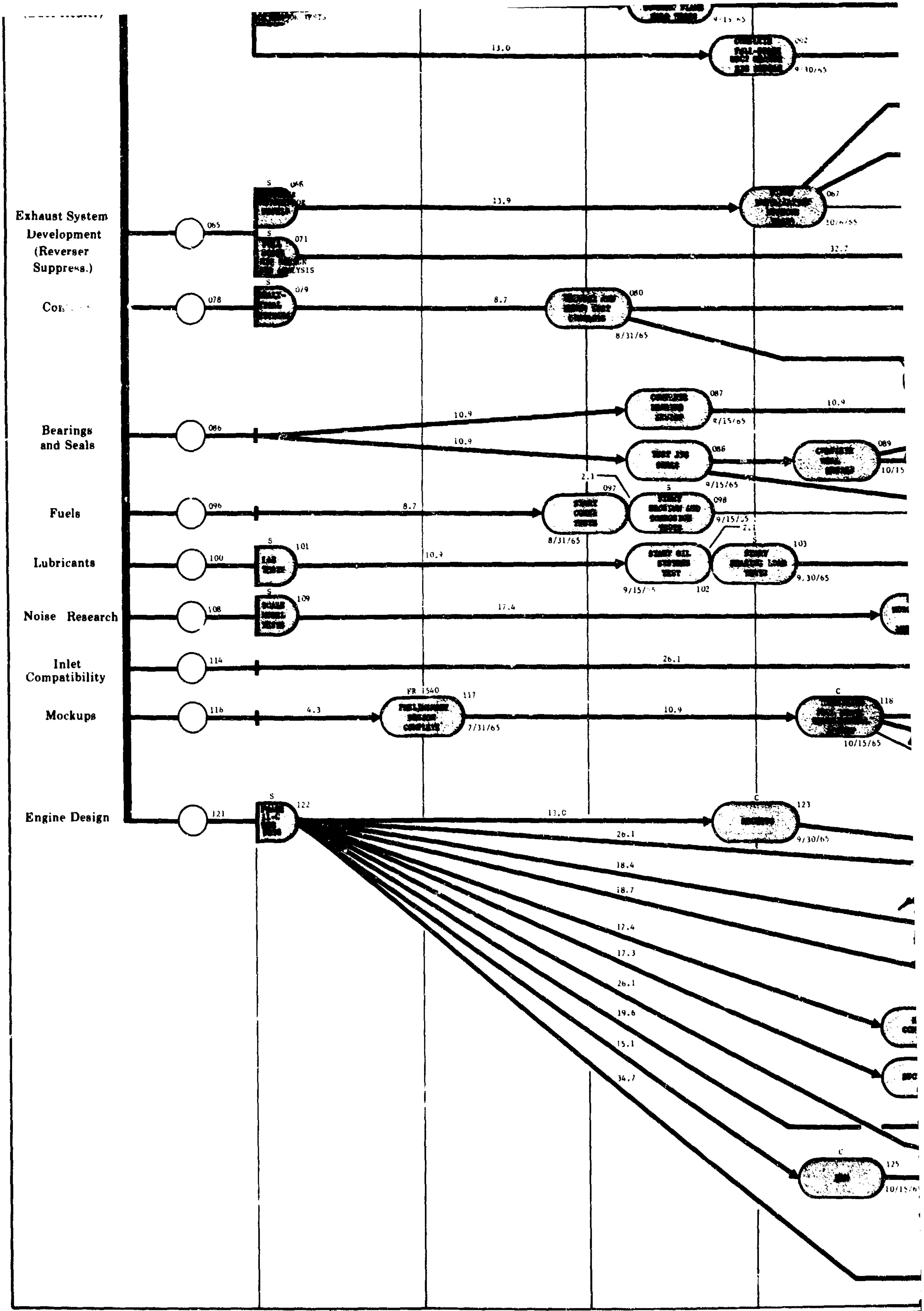
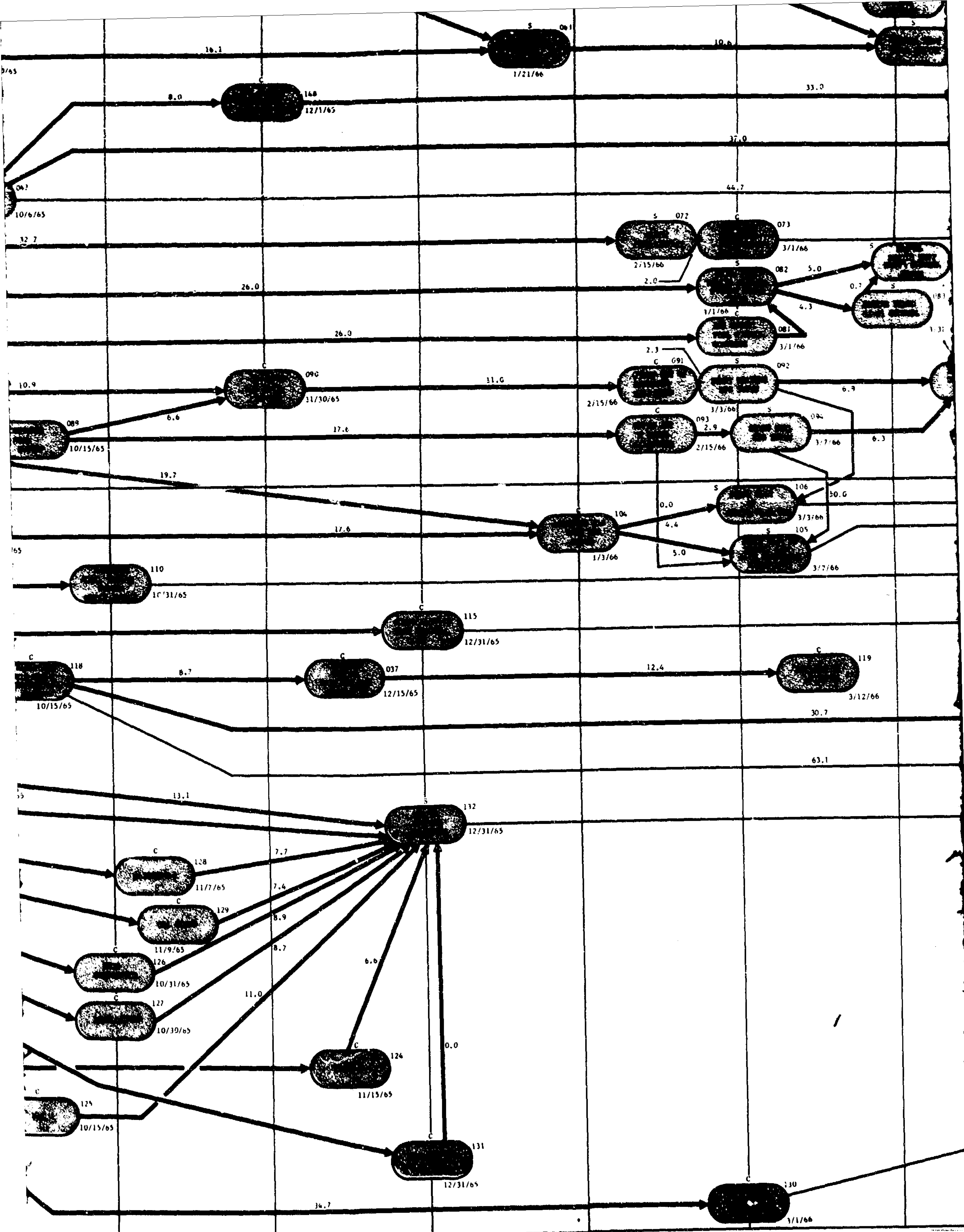
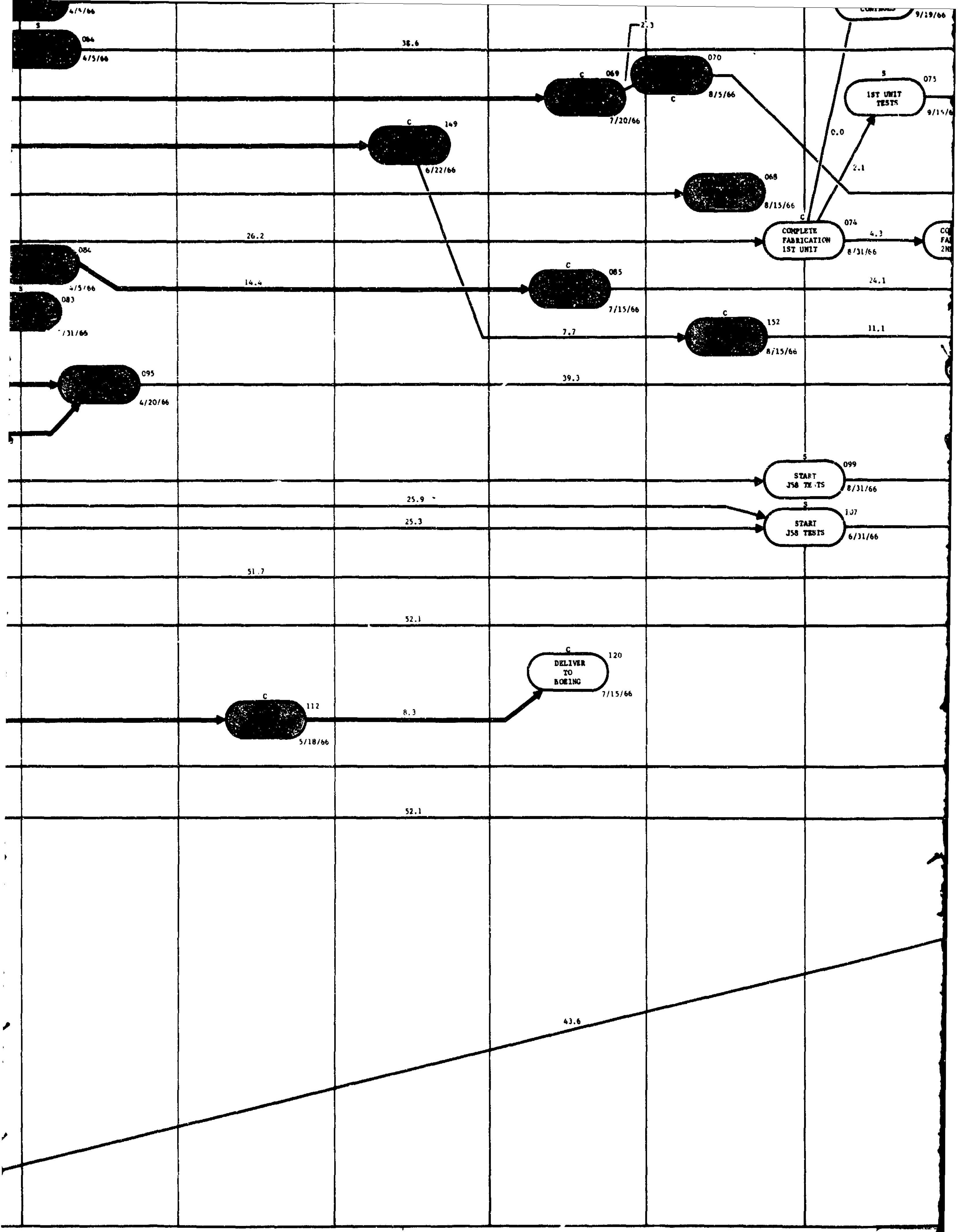


Figure 7. Management Summary Network: Development of JTF17A-20 Supersonic Transport Aircraft Engine

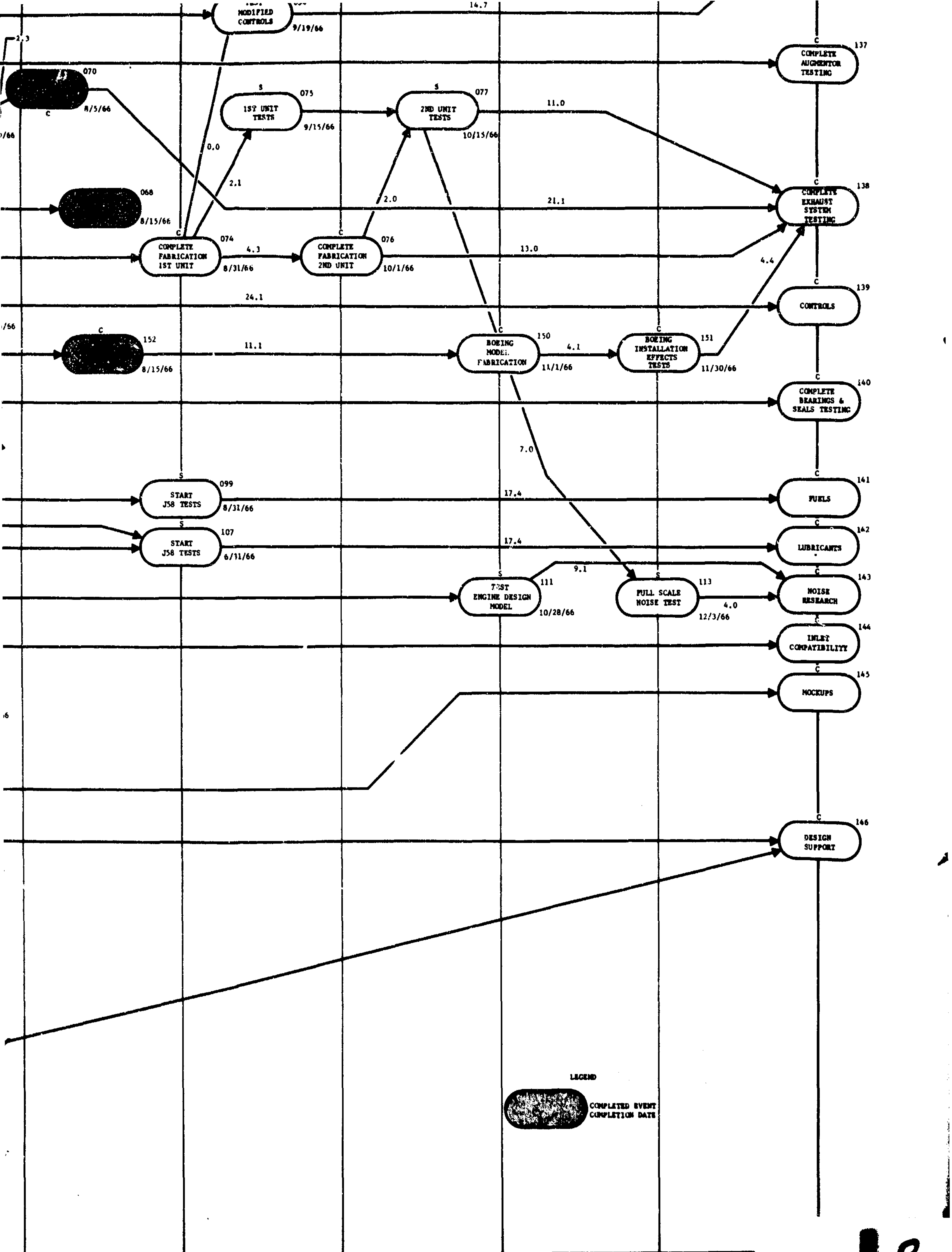


061
1/21/66
148
12/1/65
10/6/65
072
2/15/66
073
3/1/66
082
3/1/66
081
3/1/66
090
11/30/65
089
10/15/65
091
2/15/66
092
3/3/66
093
2/15/66
094
104
1/3/66
106
3/3/66
105
3/7/66
110
115
12/31/65
118
10/15/65
037
12/15/65
119
3/12/66
132
12/31/65
128
11/7/65
129
11/9/65
126
10/31/65
127
10/30/65
124
11/15/65
125
10/15/65
131
12/31/65
130
3/1/66

16


38.6
069
7/20/66
070
8/5/66
2.3
149
6/22/66
068
8/15/66
1ST UNIT
TESTS
075
9/15/66
9/19/66
0.0
2.1
26.2
COMPLETE
FABRICATION
1ST UNIT
074
8/31/66
4.3
084
4/5/66
14.4
085
7/15/66
24.1
083
7.7
152
8/15/66
11.1
095
4/20/66
39.3
START
J58 TESTS
099
8/31/66
25.9
25.3
START
J58 TESTS
51.7
52.1
DELIVER
TO
BOEING
120
7/15/66
112
5/18/66
8.3
52.1
43.6

7


MODIFIED CONTROLS
9/19/66
14.7
COMPLETE AUGMENTOR TESTING
137
070
8/5/66
1ST UNIT TESTS
075
9/15/66
2ND UNIT TESTS
077
10/15/66
11.0
0.0
2.1
2.0
068
8/15/66
21.1
COMPLETE EXHAUST SYSTEM TESTING
138
COMPLETE FABRICATION 1ST UNIT
074
8/31/66
4.3
COMPLETE FABRICATION 2ND UNIT
076
10/1/66
13.0
4.4
24.1
CONTROLS
139
152
8/15/66
11.1
BOEING MODEL FABRICATION
150
11/1/66
4.1
BOEING INSTALLATION EFFECTS TESTS
151
11/30/66
COMPLETE BEARINGS & SEALS TESTING
140
7.0
START J58 TESTS
099
8/31/66
17.4
FUELS
141
START J58 TESTS
107
6/31/66
17.4
LUBRICANTS
142
9.1
TEST ENGINE DESIGN MODEL
111
10/28/66
FULL SCALE NOISE TEST
113
12/3/66
4.0
NOISE RESEARCH
143
INLET COMPATIBILITY
144
MOCKUPS
145
DESIGN SUPPORT
146
LEGEND
COMPLETED EVENT
COMPLETION DATE

SECTION II
SIMULATION

A. ENGINE-INLET DYNAMIC SIMULATION

Pratt & Whitney Aircraft has been conducting dynamic simulation programs on the JTF17 engine control system during the past four years. These studies have resulted in the selection of the mode of control for the engine as well as the selection of the control parameters best suited to the particular mode.

During Phase II-C, these studies were conducted at the Florida Research and Development Center. The results of these studies defined in greater detail the requirements of particular sections of the control system, the response of the engine to power level transients, and the compatibility of the engine with the airframe air induction system. Data obtained from operation of the initial Phase II-C development engines have been incorporated into these studies resulting in simplification of the unitized fuel and area control.

During initial analytical and computer studies of the engine control/inlet control compatibility studies, it appeared that interconnections would be required between the two control systems. These interconnections were a Mach number signal from the air inlet control system to the engine control system and a reset signal from the engine control to the inlet control.

Initial studies suggested a Mach number signal could be utilized for automatically matching the engine airflow to the inlet characteristics. However, continuation of the studies revealed that the precision of measurement of Mach number was not sufficient to provide the required airflow control. Additional studies indicated that remote manual adjustment of engine airflow, within specific limits and incorporated in the unitized fuel and area control, could provide the flight crew the means to obtain the desired matching of inlet and engine airflow for optimum propulsion system performance at high Mach number conditions.

The use of this technique eliminates the need of any Mach number signal interface between the two control systems.

Initial evaluations of stability margins indicated that airflow transients greater than ±2% could not be tolerated at supersonic flight conditions. To provide sufficient stability margin, a reset signal was transmitted to the inlet control to reposition the shock. Both Lockheed and Boeing have since advised their respective inlet stability margins have been greatly increased and are capable of providing the required margin. Therefore, the inlet reset function has been eliminated from the JTF17 control system.

During Phase III, the computer simulation and analysis of the inlet-engine system will be continued by the airframe contractor, Pratt & Whitney Aircraft and the vendor designing and manufacturing the unitized fuel and area control. The computer work to be conducted by the airframe contractor and Pratt & Whitney Aircraft will emphasize control system compatibility of the engine and inlet controls, and the compatibility of the engine and the inlet. Computer decks will be exchanged and updated with the airframe contractor for this purpose. The control vendor program will concentrate on determining the gains, response time, and constants required within the control in order for the unit to provide the necessary control of the engine. The major overall computer effort for the engine and its control will be accomplished by Pratt & Whitney Aircraft.

A detailed simulation of the engine and its control including each major component of the control system in the form of a mathematical model computer deck will also be utilized to determine the adequacy of the design before reaching the testing phase. As testing continues the model will be revised to reflect the control characteristics determined from bench and engine testing. This component simulation will be in sufficient detail to provide a tool with which to do malfunction analysis on individual parts, such as springs, and levers. This will then provide information for the malfunction predictions.

The computer program at Pratt & Whitney Aircraft will also verify the results obtained from System studies performed by the unitized fuel and area control vendor. This verification is necessary since much of the detail design will be based on requirements which are generated by the vendor study. Thus, if a discrepancy is found in the overall system study, the necessary corrective action will be taken at the earliest opportunity.

A more detailed description of the overall dynamic simulation program conducted for the JTF17 engine is presented in Volume III, Report B, Section III.

B. MOCKUPS

Although engine mockups are not actual simulators, they do perform a function akin to a simulator. Experience has indicated the initial establishment of engine component clearances, routing of plumbing, and installation checks can be accurately defined only on mockups. During Phase II-C a full-scale mockup of the JTF17 engine has been delivered to each airframe contractor, the configuration of each being representative of the JTF17 model designed for that specific airframe. Two in-house mockups have been maintained and used as engineering design mockups. During Phase III a Class II mockup will be maintained at Pratt & Whitney Aircraft. Class II and III mockups will be supplied to the airframe contractor as required by agreement between the airframe contractor and Pratt & Whitney Aircraft. These mockups will be maintained and updated to the latest engine changes during Phase III. A complete description of the mockup is given in Volume III, Report D, Section I.

APPENDIX
EXHIBITS

The following pages present exhibits referred to in Section I of this Report. These exhibits are:

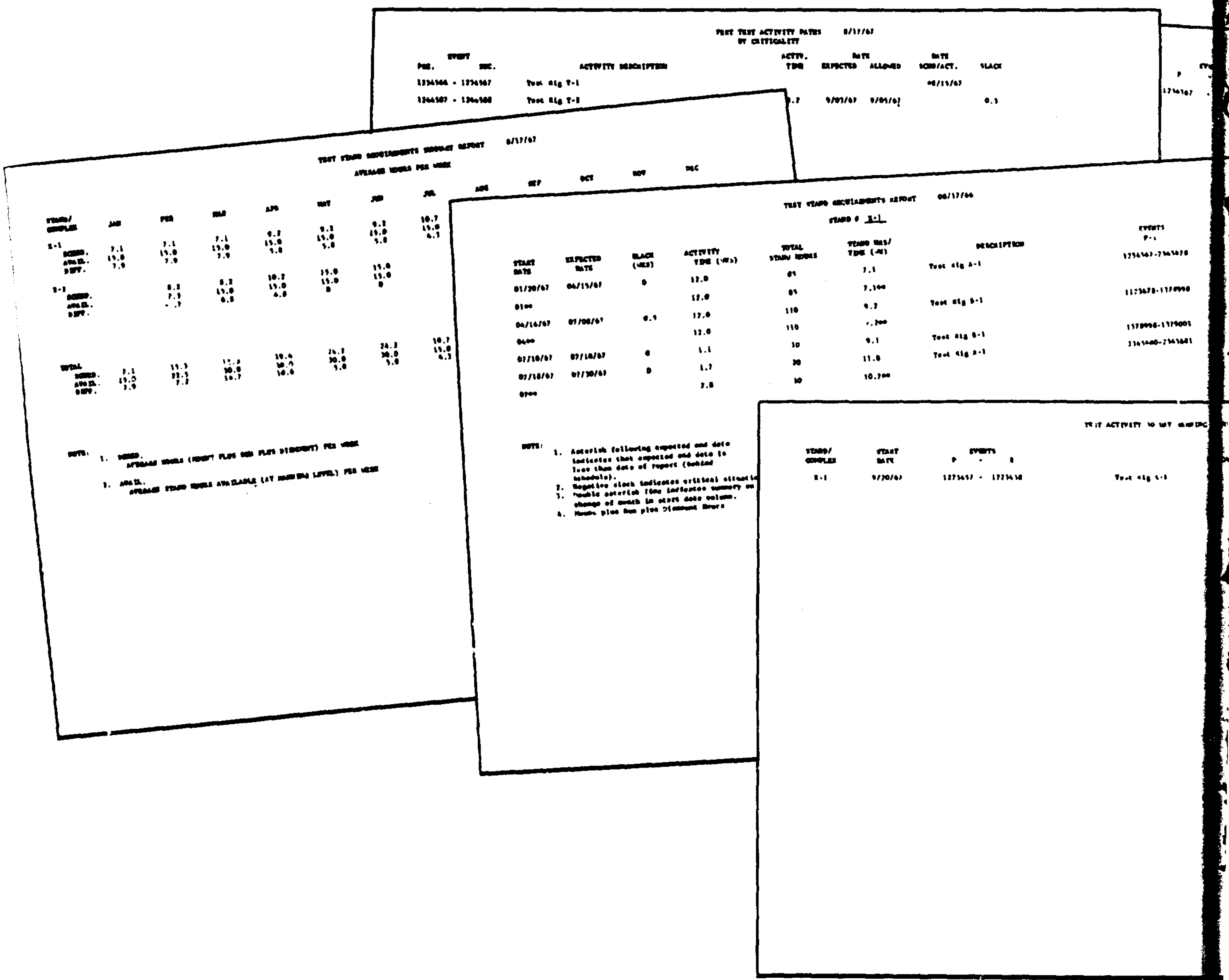
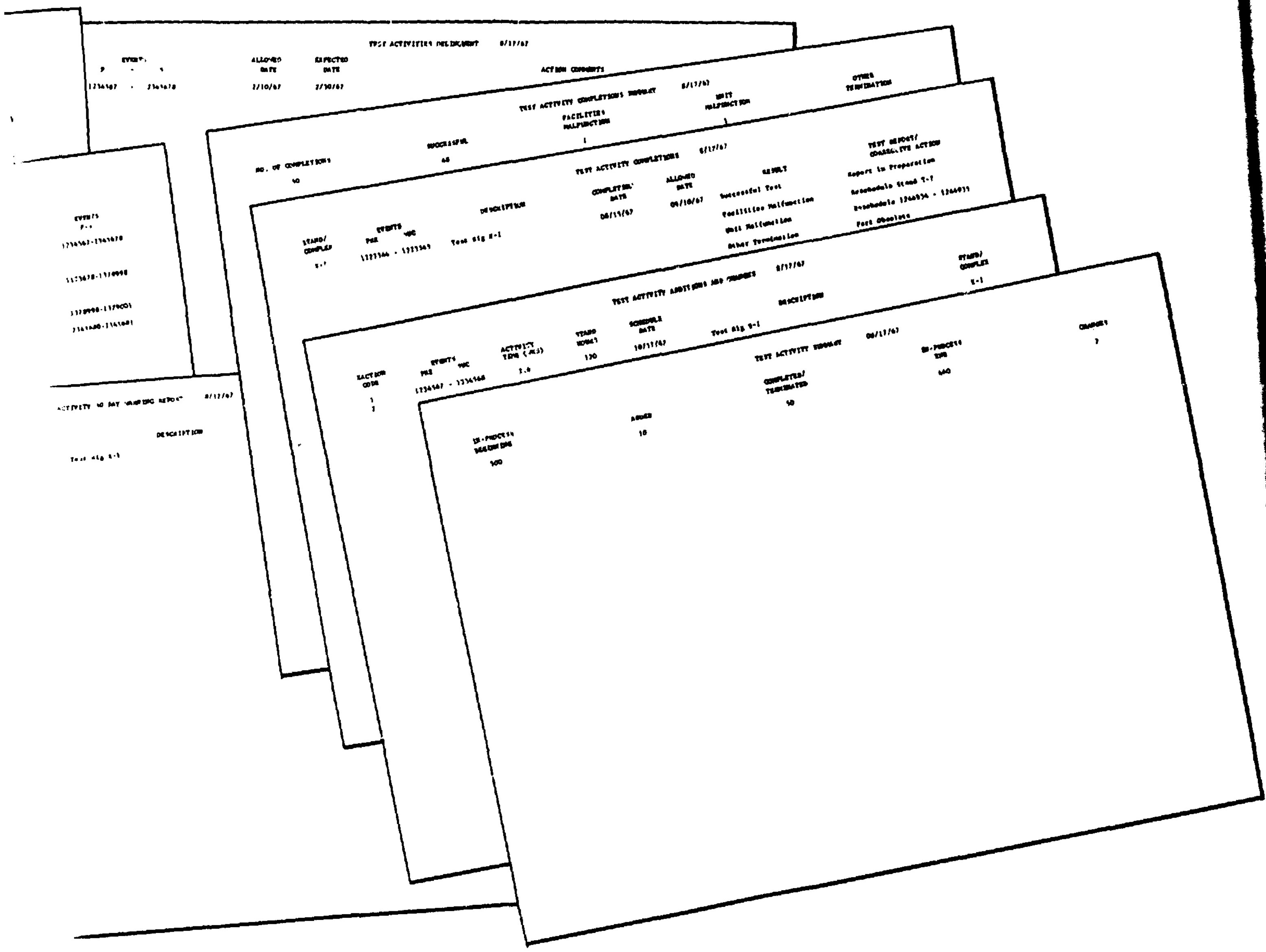
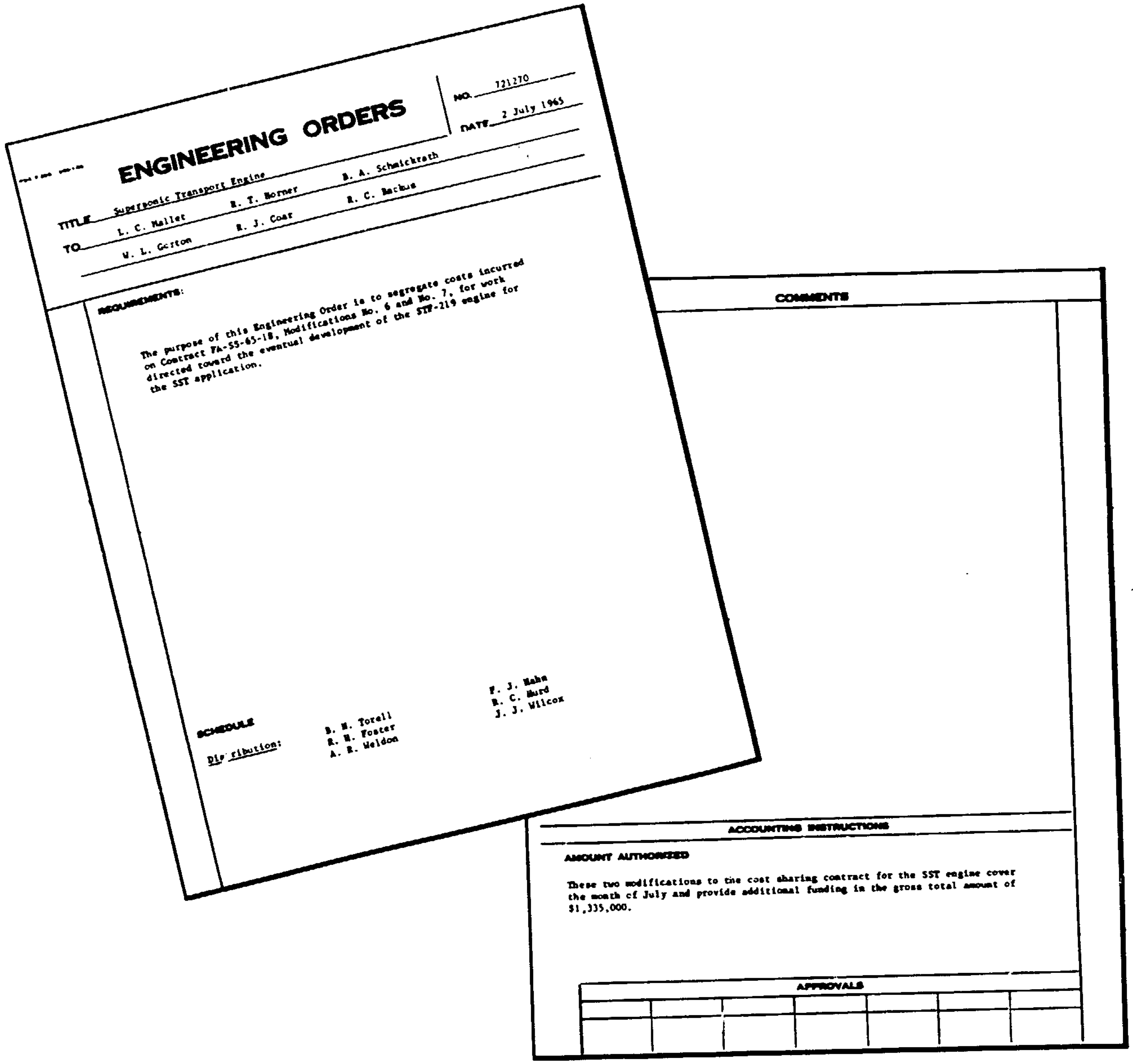


Exhibit A. Sample PREDICT Tabulation





ENGINEERING ORDERS

NO. 721270

DATE 2 July 1965

TITLE Supersonic Transport Engine

TO L. C. Mallet, R. T. Borner, B. A. Schmickrath, W. L. Gorton, R. J. Coar, R. C. Backus

REQUIREMENTS:

The purpose of this Engineering Order is to segregate costs incurred on Contract FA-SS-65-18, Modifications No. 6 and No. 7, for work directed toward the eventual development of the STF-219 engine for the SST application.

SCHEDULE

Distribution: B. H. Torell, R. H. Foster, A. R. Weldon, F. J. Hahn, R. C. Hurd, J. J. Wilcox

COMMENTS

ACCOUNTING INSTRUCTIONS

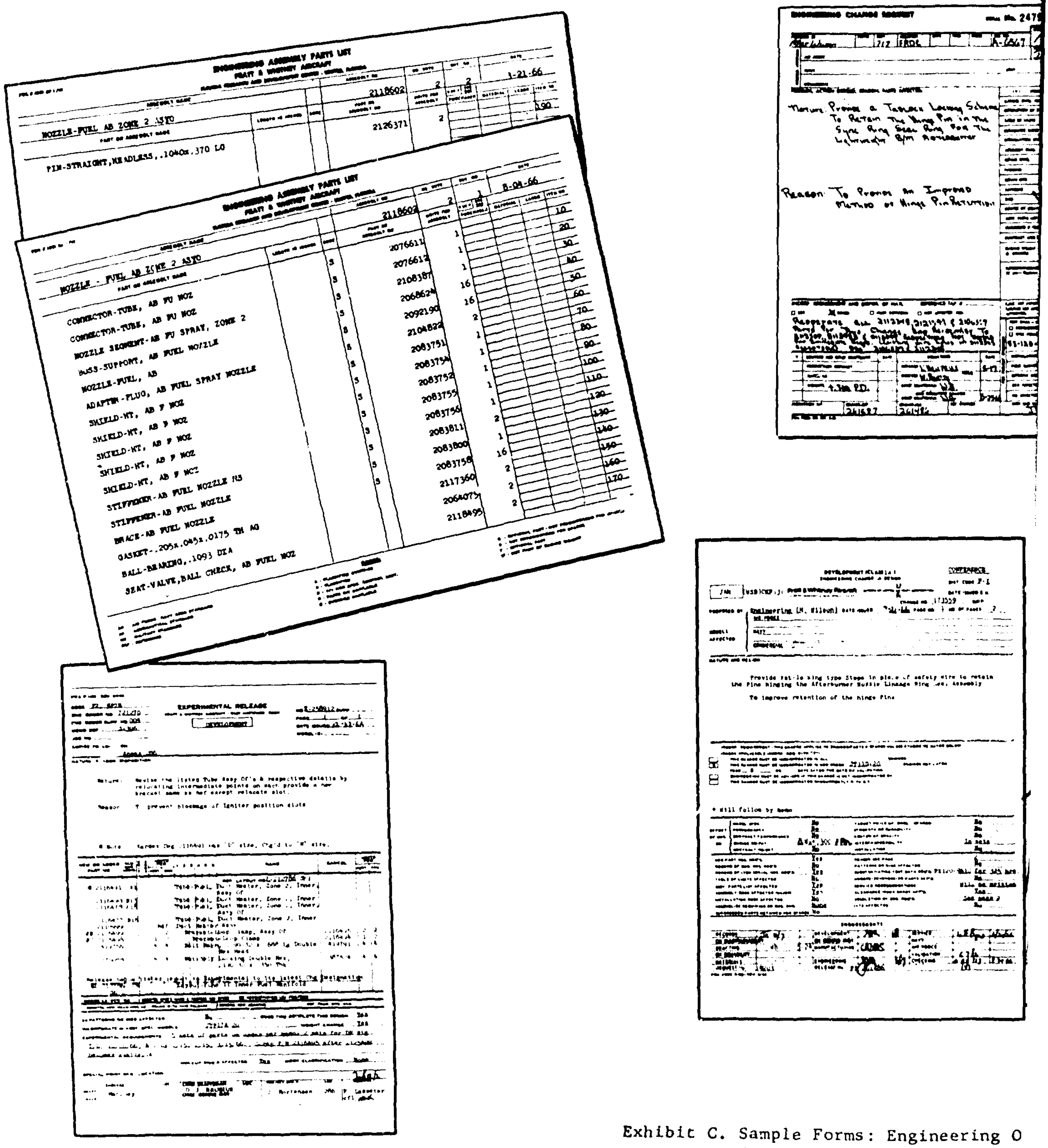
AMOUNT AUTHORIZED

These two modifications to the cost sharing contract for the SST engine cover the month of July and provide additional funding in the gross total amount of $1,335,000.

APPROVALS

FD 17908
EA

Exhibit B. Sample, Engineering Order



ENGINEERING ASSEMBLY PARTS LIST
PRATT & WHITNEY AIRCRAFT

NOZZLE-FUEL AB ZONE 2 ASYD — 2118602 — 1-21-66

PIN-STRAIGHT,HEADLESS,.1040x.370 LG — 2126371 — 2

ENGINEERING ASSEMBLY PARTS LIST
PRATT & WHITNEY AIRCRAFT

NOZZLE - FUEL AB ZONE 2 ASYD — 2118602 — 8-04-66

CONNECTOR-TUBE, AB FU NOZ	2076611	1	10
CONNECTOR-TUBE, AB FU NOZ	2076612	1	20
NOZZLE SEGMENT-AB FU SPRAY, ZONE 2	2108387	1	30
BUSS-SUPPORT, AB FUEL NOZZLE	2068624	16	40
NOZZLE-FUEL, AB	2092190	16	50
ADAPTER-PLUG, AB FUEL SPRAY NOZZLE	2104822	2	60
SHIELD-HT, AB F NOZ	2083751	1	70
SHIELD-HT, AB F NOZ	2083754	1	80
SHIELD-HT, AB F NOZ	2083752	1	90
SHIELD-HT, AB F NOZ	2083755	1	100
SHIELD-HT, AB F NOZ	2083756	1	110
STIFFENER-AB FUEL NOZZLE R3	2083811	2	120
STIFFENER-AB FUEL NOZZLE	2083800	1	130
BRACE-AB FUEL NOZZLE	2083758	16	140
GASKET-.205x.045x.0175 TH AG	2117360	2	150
BALL-BEARING,.1093 DIA	2064075	2	160
SEAT-VALVE,BALL CHECK, AB FUEL NOZ	2118495	2	170

ENGINEERING CHANGE REQUEST

Nature: Provide a Tabless Locking Scheme To Retain The Hinge Pin in The Sync Ring Seal Ring For The Unlinked B/M Afterburner

Reason: To Provide An Improved Method of Hinge Pin Retention

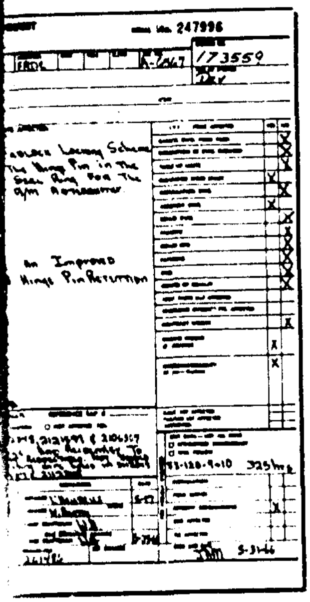
EXPERIMENTAL RELEASE

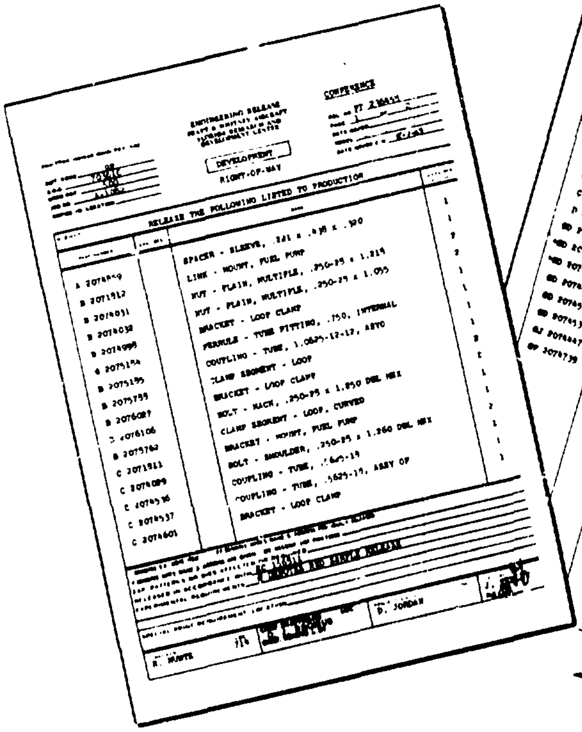
DEVELOPMENT

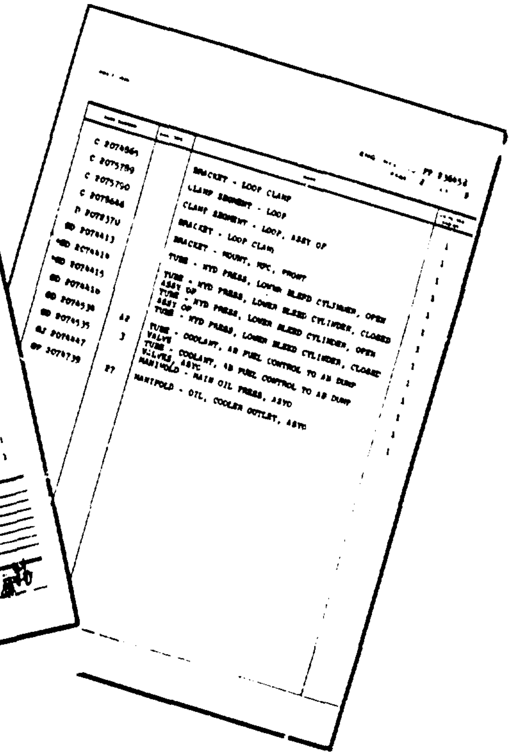
Provide tab-lo king type Stops in place of safety wire to retain the Pins hinging the Afterburner Nozzle Linkage Ring ... Assembly

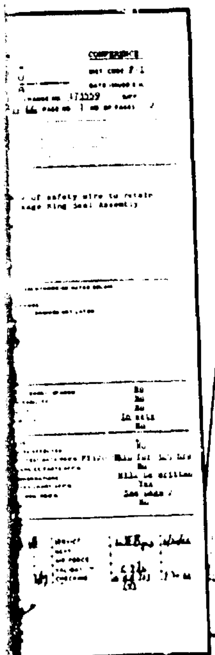
To improve retention of the hinge Pins

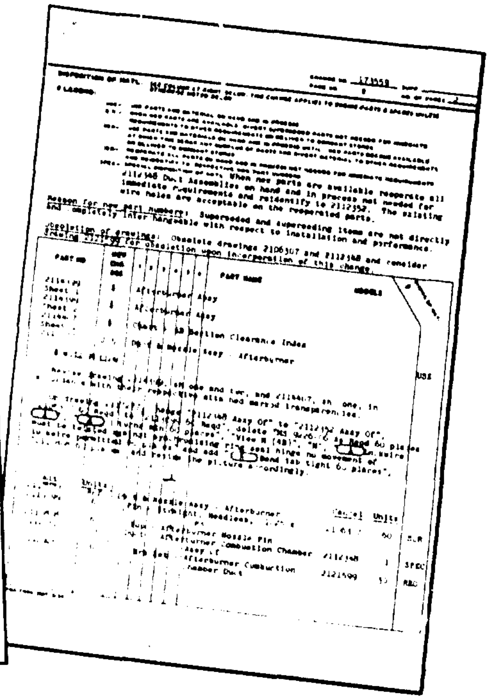
Exhibit C. Sample Forms: Engineering O
Experimental Release, Engin
Parts List, Engineerin
Change Request, Engine

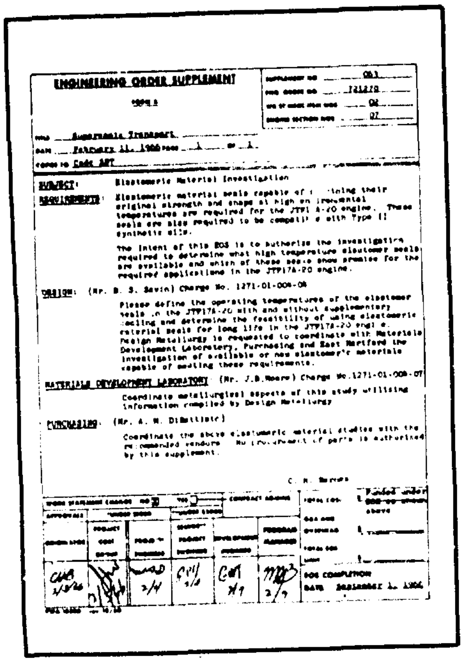












Engineering Order Supplement,
elease, Engineering Assembly
gineering Release, Engineering
, Engineering Change in Design

FD 17802
EA

ENGINEERING SOURCE APPROVAL DATA LIST

Part Spec. No.(s) and Name(s): 2118702, 2122401, 2122301 BLADE, FAN

ENGINE TYPE: CODE XX JTF17

REFERENCE RELEASE NO: E258874

DATE: 12-7-65

DISTRIBUTION

REASON	SOURCE	CHECK COMPL'D PART
1A	THOMPSON-RAMO-WOOLDRIDGE, JET & ORD DIV TRW INC (FOR TRW FORGINGS ONLY)	
1A	HAL TOOL & ENG CO, MANCHESTER, CONN.	
1B	THOMPSON-RAMO-WOOLDRIDGE, JET & ORD DIV TRW, INC, CLEVELAND OHIO	
1B	WYMAN-GORDON CO, WORCESTER, MASS.	
1B	LADISH CO, CUDAHY, WIS	
1C	TITANIUM METALS CORP OF AMERICA, W. CALDWELL, N.J.	
1C	REACTIVE METALS, INC, NILES, OHIO	

REMARKS:

DEC 8 1965
Engrg Records
P. & W. A.

REASON DESIGNATIONS:

1. MANUFACTURING EXCELLENCE OF VITAL PART
   Indicate applicable sources under this reason for one or more of the following:
   Manufacturing Process
   Forging or Casting
   Ingot
   Special Processing
2. ASSEMBLY TECHNIQUES
3. BONDING TECHNIQUES
4. MOLDING TECHNIQUES
5. MOLD OR DIE DESIGN AND CONSTRUCTION
6. DIMENSIONAL CONTROL OF UNDIMENSIONED FEATURES
7. PERFORMANCE REQUIREMENTS, ADJUSTMENTS, ETC
8. MATERIAL OF PART
   Composition and/or physical properties
9. MATERIAL PROCESSING
   Raw Material Process
   - A INGOT
   - B BAR
   - C SHEET OR STRIP
   - D FORGING
   - E CASTING
   - F WELDED RING
   - G TUBING

   Manufacturing Process
   - H MACHINING
   - I GRINDING
   - J FORMING
   - K WELDING
   - L BRAZING
   - M HEAT TREATING
   - N PLATING/COATING
10. SPECIAL

PART & ASSEMBLY SIGNATURES		MATERIAL & PROCESS SIGNATURES	
Design Analyst	Carl E. Anderson	Spec Engr	Chief Engr Production
Chief Draftsman		Mat'l Engrg	Metallurgical Engr (FRDC)
Project Engr		Eng Design	

NOTES

1. Enter the number (and letter) designation of applicable reasons in the "REASON" column. See extreme left hand column for correct reason designations.
2. Enter sources selected by Project Engineer in "SOURCE" column opposite the indicated reason. Write "Source will follow" in "SOURCE" column if Project Engineer is to select source at later date. When a special source has been indicated for reason 1, or when reason 10 is used, a brief explanation must also appear in the "SOURCE" column — e.g. "Special broaching" or "Special Material cleanliness to conform to manufacturer's specifications." When reason 8 is used, also give specification number or name of material in "SOURCE" column.
3. More than one reason designation may be entered opposite a given source.
4. Place a check mark in the "COMPLETED PART" column if source supplies completed part.
5. For non-VFI items, explain under "REMARKS" why there is no source option if only one source is listed against a given reason. Each explanation must be prefaced by "Reason X" where "X" is the number of the applicable reason.

PWA FORM 3032 REV 4-64 (Standard Procedure F-6)

Exhibit D. Engineering Source Approval Data List

FD 17856
EA

INTER-OFFICE CORRESPONDENCE
PERMANENT MEMORANDUM FOR FILE

Pratt & Whitney Aircraft — UA

FLORIDA RESEARCH and DEVELOPMENT CENTER

To: G. A. Titcomb

Date: July 18, 1966

From: M. F. Porto

Ext:

Subject: Weekly Report - SST Program

1. Rigs

   A. 0.6 Fan Compressor Rig - no requirements.

   B. Hi Compressor Rig (35010) - no requirements.

   C. Primary Combustor in JT4 - no requirements.

   D. Duct Heater Rig - no requirements.

   E. Bearings and Seal Rigs - no requirements.

   F. Gearbox Rigs - no requirements.

2. Engines

   A. FX-161 - no requirements.

   B. FX-162 - no requirements.

   C. FX-163

1.	Fan disks	Complete
2.	Fan stators	Use first stage case from FX-162 - 7/29
3.	Fan blades	7/23 from Mal Tool
4.	Front mount case	Estimate 8/5
5.	Variable stators assembly	Engineering to supply (third stage 8/10 for replacement parts)
6.	Fixed Stators	Engineering to supply
7.	Hi compressor blades	Engineering to supply
8.	Hi compressor disks	7/25 paced by third stage
9.	Hi compressor spacers	Stages 3-4 and 6-7 - 7/22
10.	Intermediate case	7/22 Assembly
11.	Main diffuser case	Complete
12.	Fan duct diffuser cone	7/25
13.	Outer burner cases	8/4
14.	Deflector assembly	7/20
15.	Turbine rear nozzle case	Complete
16.	Turbine disks	1st-and 2nd-stage complete; 3rd-stage 7/19
17.	Turbine hub - rear	Complete
18.	Turbine blades	1st-stage 7/27; 2nd-stage 7/25; 3rd-stage 7/20

PWA FORM 8 REV. 10-65

Exhibit E. Sample Page, Weekly Report - SST Program

FD 17909
EA

SUPPLEMENT TO EXPERIMENTAL ASSEMBLY ORDER

SUBJECT Rig 30130-15 W.O. NO.

SECTION Rig Section ENGINEER Daelemans/Price TEL.

Approved by:
[redacted] E. F. Tatum DATE

ITEM	REQUIREMENTS	WORK BY CLOCK	WORK BY DATE
1	Please accept all rig parts from teardown memo of 30130-14		
2	Please accept P/N 2127001 1st turbine blade and send out to be slotted and instrumented per FKB 6141		
3	Please accept two slave blades P/N 2126701 and send out to be slotted and instrumented per a modified FKB 6141		
4	Please instrument rig per memo dated 20 May 1966 to T. F. Lewis from C. Paul Daelemans		
5	Please build up rig per TL 213174 and TL 211179		
6	Please ship rig to C-1A test stand		

ASSEMBLERS WILL SIGN CLOCK NUMBER AND DATE FOR WORK DONE

WORK CHECKED BY __________ DATE __________
Assembly Foreman

PWA PROC 84 (WAS 10115) REV. 8-62

Exhibit F. Experimental Assembly Order - Rig Section FD 17857 EA

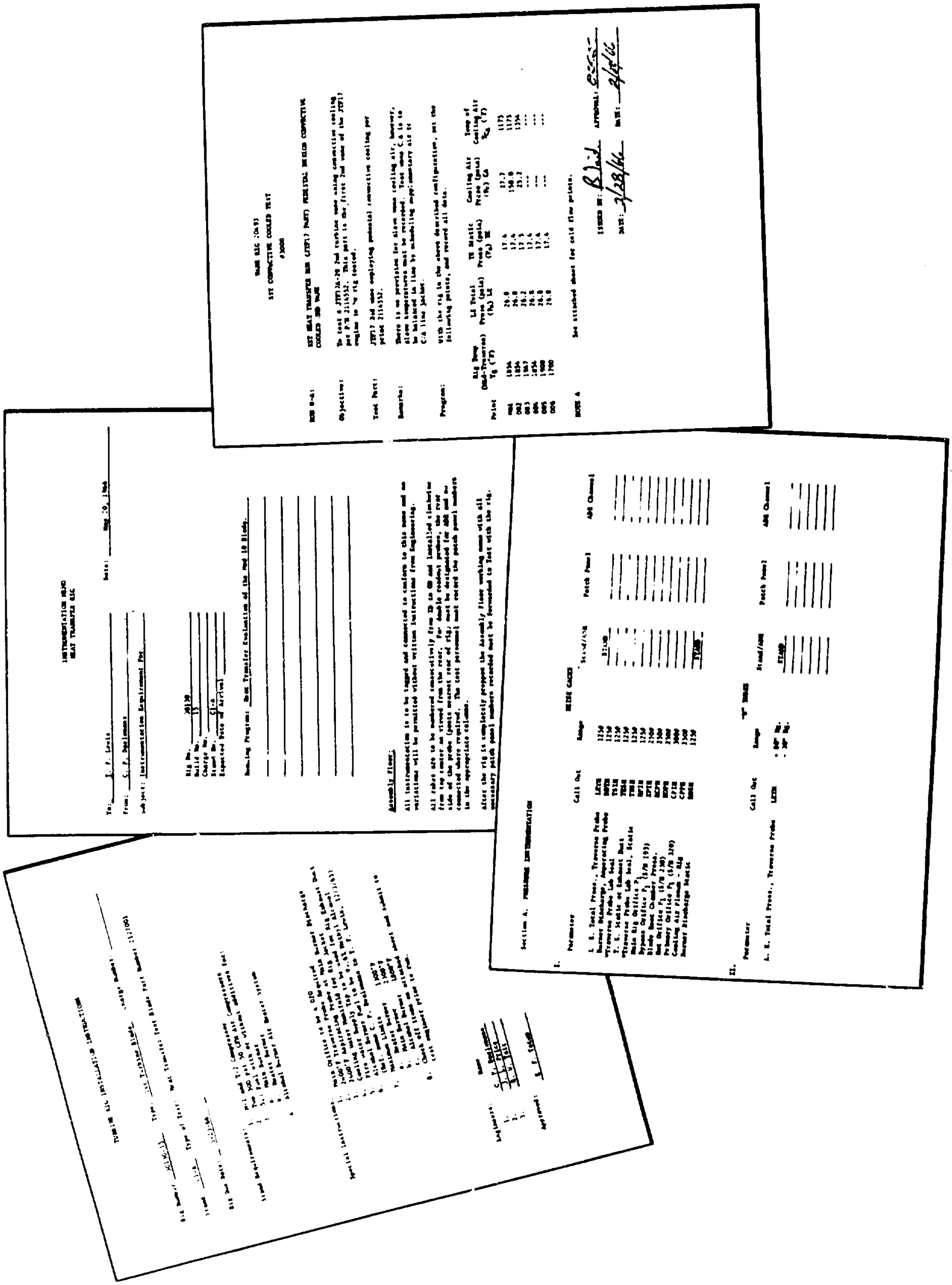
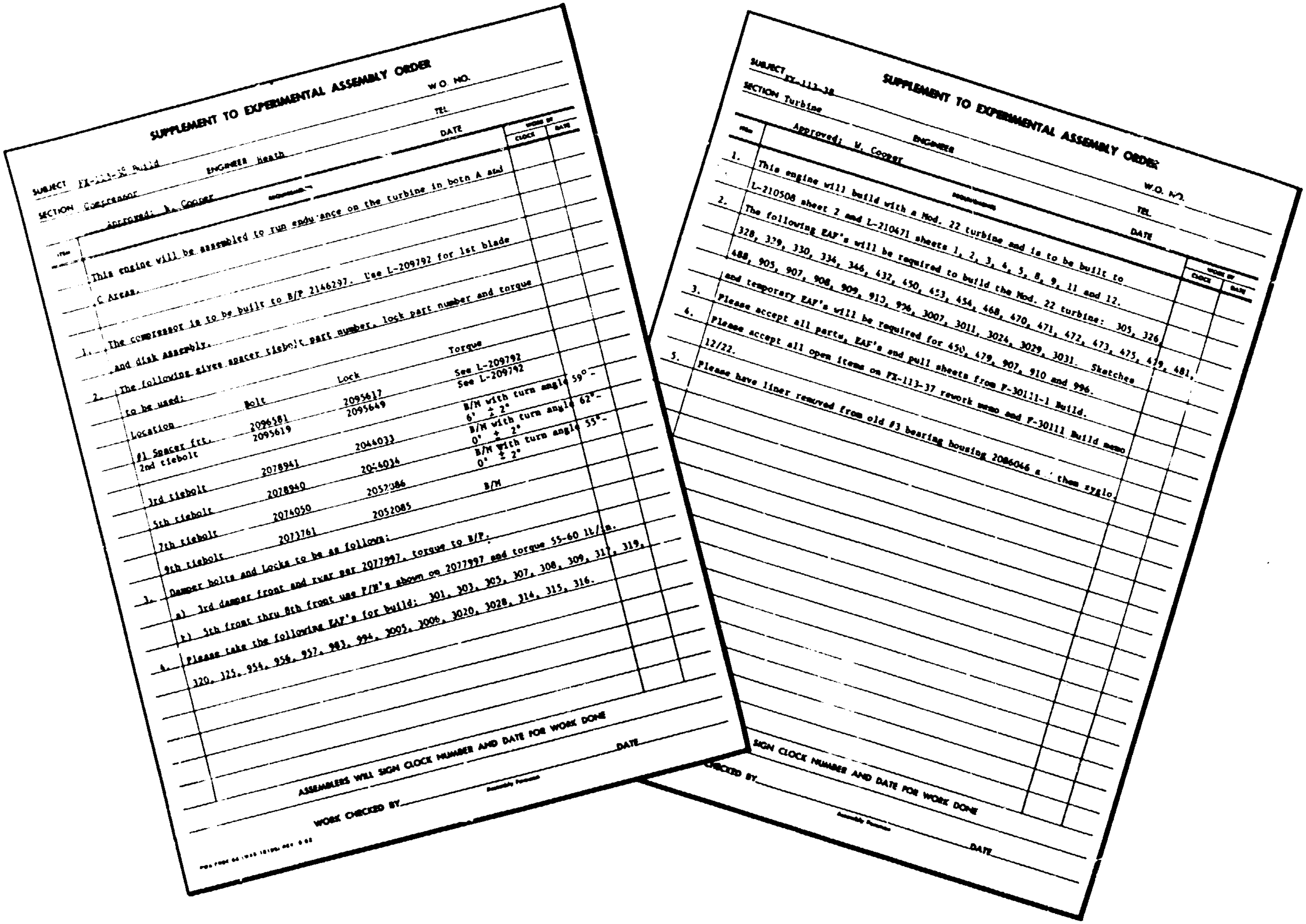


Exhibit G. Sample Pages, Turbine Rig Installation, Instrumentation, and Running Instructions

FD 17905
EA

FD 17842
EA



SUPPLEMENT TO EXPERIMENTAL ASSEMBLY ORDER

SUBJECT FX-113-38 Build
SECTION Compressor
ENGINEER Heath
Approved: W. Cooper
W.O. NO.
TEL.
DATE

ITEM		WORK BY CLOCK	DATE
	This engine will be assembled to run endurance on the turbine in both A and C Areas.		
1.	The compressor is to be built to B/P 2146297. Use L-209792 for 1st blade and disk assembly.		
2.	The following gives spacer tiebolt part number, lock part number and torque to be used:		

Location	Bolt	Lock	Torque
#1 Spacer frt.	2096381	2095617	See L-209792
2nd tiebolt	2095619	2095649	See L-209792
		2044033	B/M with turn angle 59° - 6° ± 2°
3rd tiebolt	2078941	2044034	B/M with turn angle 62° - 0° ± 2°
5th tiebolt	2078940	2052086	B/M with turn angle 55° - 0° ± 2°
7th tiebolt	2074050	2052085	B/M
9th tiebolt	2073761		

3. Damper bolts and Locks to be as follows:
a) 3rd damper front and rear per 2077997, torque to B/P.
b) 5th front thru 8th front use P/N's shown on 2077997 and torque 55-60 lb/in.
4. Please take the following EAP's for build: 301, 303, 305, 307, 308, 309, 317, 319, 320, 325, 954, 956, 957, 983, 994, 3005, 3006, 3020, 3028, 314, 315, 316.

ASSEMBLERS WILL SIGN CLOCK NUMBER AND DATE FOR WORK DONE

WORK CHECKED BY ______ DATE ______
Assembly Foreman

SUPPLEMENT TO EXPERIMENTAL ASSEMBLY ORDER

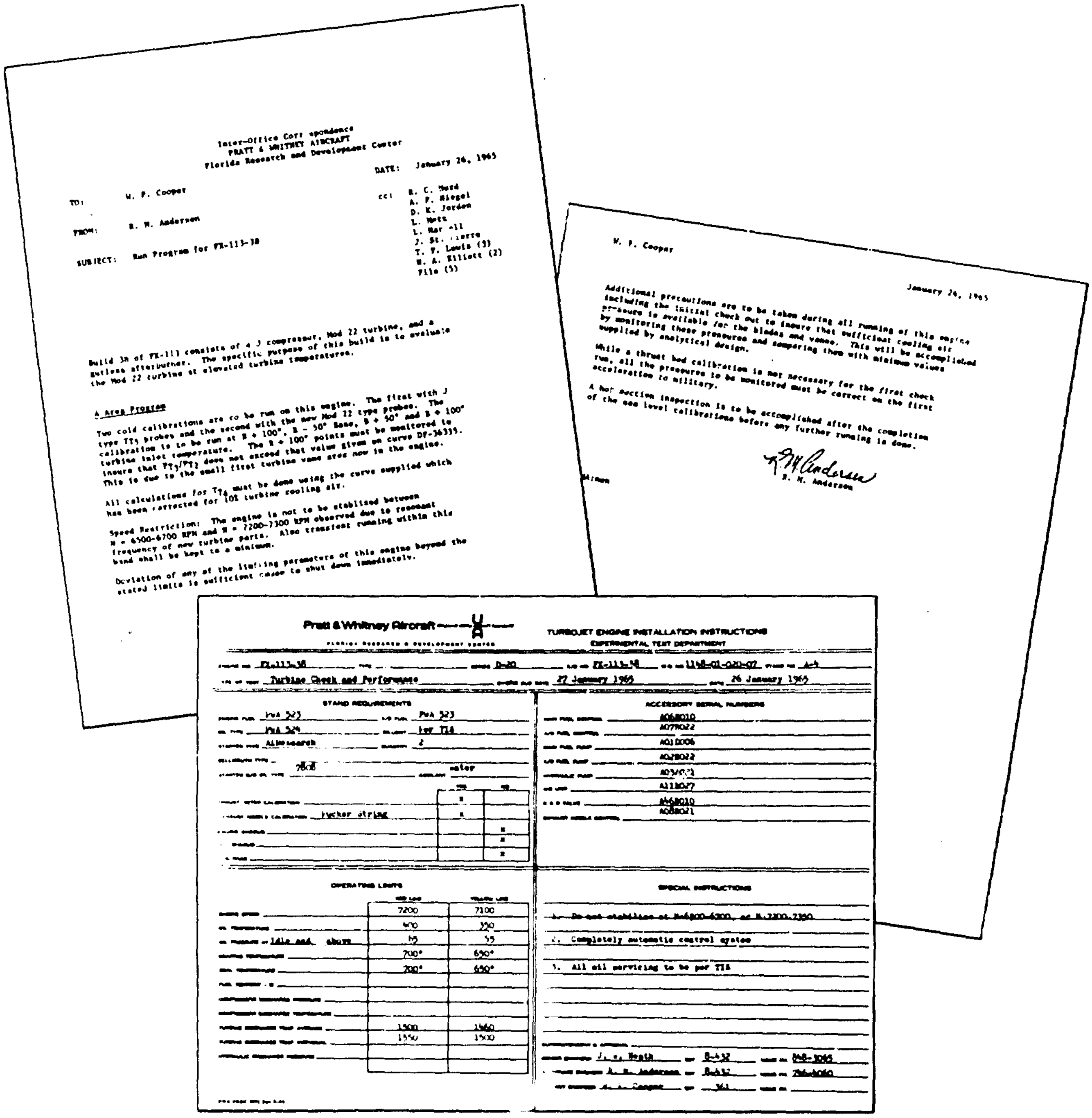
SUBJECT FX-113-38
SECTION Turbine
ENGINEER
Approved: W. Cooper
W.O. NO.
TEL.
DATE

ITEM		WORK BY CLOCK	DATE
1.	This engine will build with a Mod. 22 turbine and is to be built to L-210508 sheet 2 and L-210471 sheets 1, 2, 3, 4, 5, 8, 9, 11 and 12.		
2.	The following EAP's will be required to build the Mod. 22 turbine: 305, 326, 328, 329, 330, 334, 346, 432, 450, 453, 454, 468, 470, 471, 472, 473, 475, 479, 481, 488, 905, 907, 908, 909, 910, 996, 3007, 3011, 3024, 3029, 3031. Sketches and temporary EAP's will be required for 450, 479, 907, 910 and 996.		
3.	Please accept all parts, EAP's and pull sheets from F-30111-1 Build.		
4.	Please accept all open items on FX-113-37 rework memo and F-30111 Build memo 12/22.		
5.	Please have liner removed from old #3 bearing housing 2086046 a ' them syglo.		

SIGN CLOCK NUMBER AND DATE FOR WORK DONE

CHECKED BY ______ DATE ______
Assembly Foreman

Exhibit H. Sample Pages, J58 Engine Assembly Instructions



Inter-Office Correspondence
PRATT & WHITNEY AIRCRAFT
Florida Research and Development Center

DATE: January 26, 1965

TO: W. P. Cooper

FROM: R. M. Anderson

SUBJECT: Run Program for FX-113-38

cc: R. C. Murd, A. P. Riegel, D. K. Jordan, L. Mett, L. Mar ell, J. St. Pierre, T. F. Lewis (3), W. A. Elliott (2), File (5)

Build 38 of FX-113 consists of a J compressor, Mod 22 turbine, and a gutless afterburner. The specific purpose of this build is to evaluate the Mod 22 turbine at elevated turbine temperatures.

A Area Program

Two cold calibrations are to be run on this engine. The first with J type TT5 probes and the second with the new Mod 22 type probes. The calibration is to be run at B + 100°, B - 50° Base, B + 50° and B + 100° turbine inlet temperature. The B + 100° points must be monitored to insure that PT3/PT2 does not exceed that value given on curve DF-36335. This is due to the small first turbine vane area now in the engine.

All calculations for TT4 must be done using the curve supplied which has been corrected for 10% turbine cooling air.

Speed Restriction: The engine is not to be stabilized between N = 6500-6700 RPM and N = 7200-7300 RPM observed due to resonant frequency of new turbine parts. Also transient running within this band shall be kept to a minimum.

Deviation of any of the limiting parameters of this engine beyond the stated limits is sufficient cause to shut down immediately.

W. P. Cooper

January 26, 1965

Additional precautions are to be taken during all running of this engine including the initial check out to insure that sufficient cooling air pressure is available for the blades and vanes. This will be accomplished by monitoring these pressures and comparing them with minimum values supplied by analytical design.

While a thrust bed calibration is not necessary for the first check run, all the pressures to be monitored must be correct on the first acceleration to military.

A hot section inspection is to be accomplished after the completion of the sea level calibrations before any further running is done.

R. M. Anderson

Pratt & Whitney Aircraft
TURBOJET ENGINE INSTALLATION INSTRUCTIONS
EXPERIMENTAL TEST DEPARTMENT

FX-113-38 D-20 FX-113-38 1148-01-020-07
Turbine Check and Performance 27 January 1965 26 January 1965

STAND REQUIREMENTS
PWA 523 PWA 523
PWA 524 Per TIS
AiResearch 2
Tucker string

ACCESSORY SERIAL NUMBERS
A068010
A079022
A010006
A028022
A113027
A068010
A068021

OPERATING LIMITS
7200 7100
1500 1460
1550 1500

SPECIAL INSTRUCTIONS
1. Do not stabilize at N=6500-6700, or N=7200-7300
2. Completely automatic control system
3. All oil servicing to be per TIS

J. E. Heath
R. M. Anderson

Exhibit I. Sample Pages, J58 Engine Installation Instructions FD 17841 EA

INSTRUMENTATION MEMO
J58 ENGINE

To: T. F. Lewis

From: R. M. Andersen

Date: 1-29-65

Subject: Instrumentation Requirement for:

Build Number FX-113
Cost Control No. 38
Stand Number 1148-01-020-07
Expected Date of Arrival A-2 3-4-65

cc: H. A. Elliott (5)
S. E. Hood (3)
Test Area Supervisor (2)
Test Area General Foreman
B. Meyer (2)
R. Bocinski
J. K. Lang
D. K. Jorden
W. Cooper
File (5)

Running Program: 50 hr endurance at 625° inlet temperature.

ADR will be required for first five hours and set ups will be for 74,000 feet data points.

Additional Remarks: See run program.

Assembly Floor

All instrumentation is to be tagged and connected to conform to this memo and no variations will be permitted without written instructions from Engineering.

All rakes are to be numbered consecutively from ID to OD and installed clockwise from top center as viewed from the rear. For double readout probes, the rear side of the probe (posts nearest rear of engine) must be designated for ADR and so connected where required. The Assembly Floor must record the patch panel numbers in the appropriate columns.

After the engine is completely prepped the Assembly Floor working memo with all necessary patch panel numbers recorded must be forwarded to test with the engine.

Test Stand

The appropriate patch panel numbers, channel numbers and jumper connector numbers are to be filled in by the stand personnel and upon completion of each hook-up will be signed by the individual concerned.

STANDARD INSTRUMENTATION

1. Pressures

Parameter	Engine Tag	Range	Remarks	ACR/CDR or Stand	Shroud Patch	Jumper Connector	Patch & Channel No.	Initials
Inlet	P_{T_2}-1	0-100"	HgA	BOTH				
	-2							
	-3							
	-4							
	-5							
Inlet Differential	P_{T_2}-P_{S_2}-1	0-100"	Br	BOTH				
	-2							
	-3							
	-4							
	-5							
	-6							
Compressor Discharge	P_{T_3}-1A	0-125	Psia	BOTH				
	-2A							
	-3A							
	-4B							
	-5B							
Turbine Discharge	P_{T_5}-1	0 100"	Hg	BOTH				
	-2							
	-3							
	-4							
	-5							
Burner	P_B	0-125	Psia	BOTH				
	false P_B	0-125	Psia	BOTH				
Orifice Upstream Statics	(1) Stand							
	(2) Stand							
	(3) Stand							
	(4) Stand							
	(5) Stand							

Exhibit J. Sample Pages Instrumentation Memo - J58 Engine

FD 17910
EA

Pratt & Whitney Aircraft

INTER-OFFICE CORRESPONDENCE

FLORIDA RESEARCH AND DEVELOPMENT CENTER

Date 23 March 1966

To E. F. Tatum

From R. W. Tait

Subject Heat Transfer Test of a JTF17 2nd-Stage Turbine Vane, F/M

Reference: Memo, S. F. Hooker to Mr. E. F. Tatum, 2-4-66, "Heat Transfer Test of Two-pass Convective/Film Cooled Blade per L-213176

Objective: To test the heat transfer characteristics of a JTF17 2nd-stage vane at SST cruise conditions and to gather data for a radiation calibration.

Configuration:

1. Main Rig

Rig 20493 consists of forward and rear spool sections with a test specimen mounting plate between. The forward section contains a sheet metal duct making the transition from the burner can cross section to the test specimen. The duct simulates the gas stream entrance conditions of the engine. A tailboard is incorporated at the trailing edge of the test specimen, both to direct gas flow and act as a radiation shield.

The rig is "uncooled."

The rig was mounted in C-1A stand 2/28/66 and testing continued through 3/3/66.

The rig was instrumented per AKY 2571. See figure 1.

2. Cooling Air System

As described in Reference.

3. Test Part

The test specimen was a cast JTF17 2nd-stage vane as shown on B/P 2114552. See figure 2. This is a pedestal supported convectively cooled vane. The cooling air enters at OD platform and passes spanwise through the vane exiting through the ID platform.

Instrumentation of the quarter tip, midspan and quarter root locations was established using 0.020 in. ceramo thermocouples embedded in the airfoil surface per AKY 2497. See figures 3 and 3A.

...e "U-Program #3000," was written to provide
...the "Test Objective." See figure 4.

...lation from the run program. Two cold flows
...ctual heat transfer test and one following

...gure 5 shows four separate chordwise tem-
...h are raw rig data for two cooling air flows,
...w. The three remaining curves are inter-
...cooling air flow. The main rig conditions
... conditions. The rerun of the SST cruise
...n be seen in figure 5.

...parison of one quarter tip and midspan
...iles, for SST cruise conditions. All
... plane were out.

... test without main rig flow is presented
...e in flow characteristics prior to and after
...y with main rig flow at simulated SST
...ame flow characteristics as without rig
...he cooling air exits the vane out of the

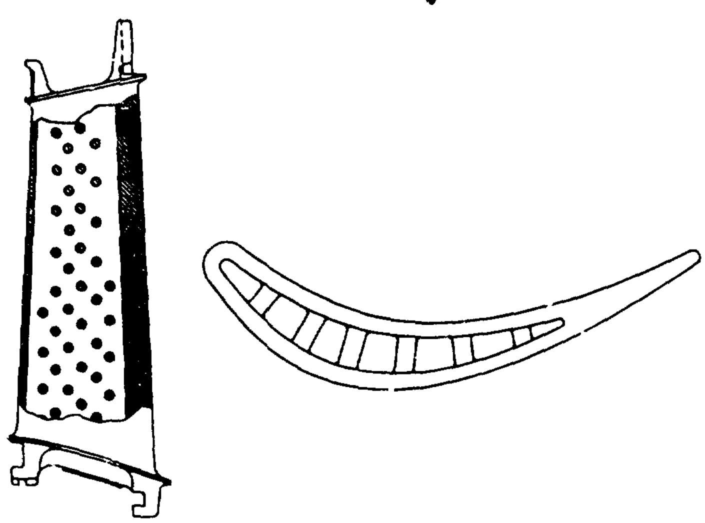
...s included, figure 8. This shows a comparison
...f-the art for first vanes. The second vane
...d be noted that first vanes employ impingement
...tal temperature for a given configuration.
...rage metal temperature, φ's are higher for

...age in the rig and the data presented

...equired cooling effectiveness for
...ooling air flow. This test demonstrates
... slightly over 0.31 at 1% cooling airflow.

RW Tait
R. W. Tait

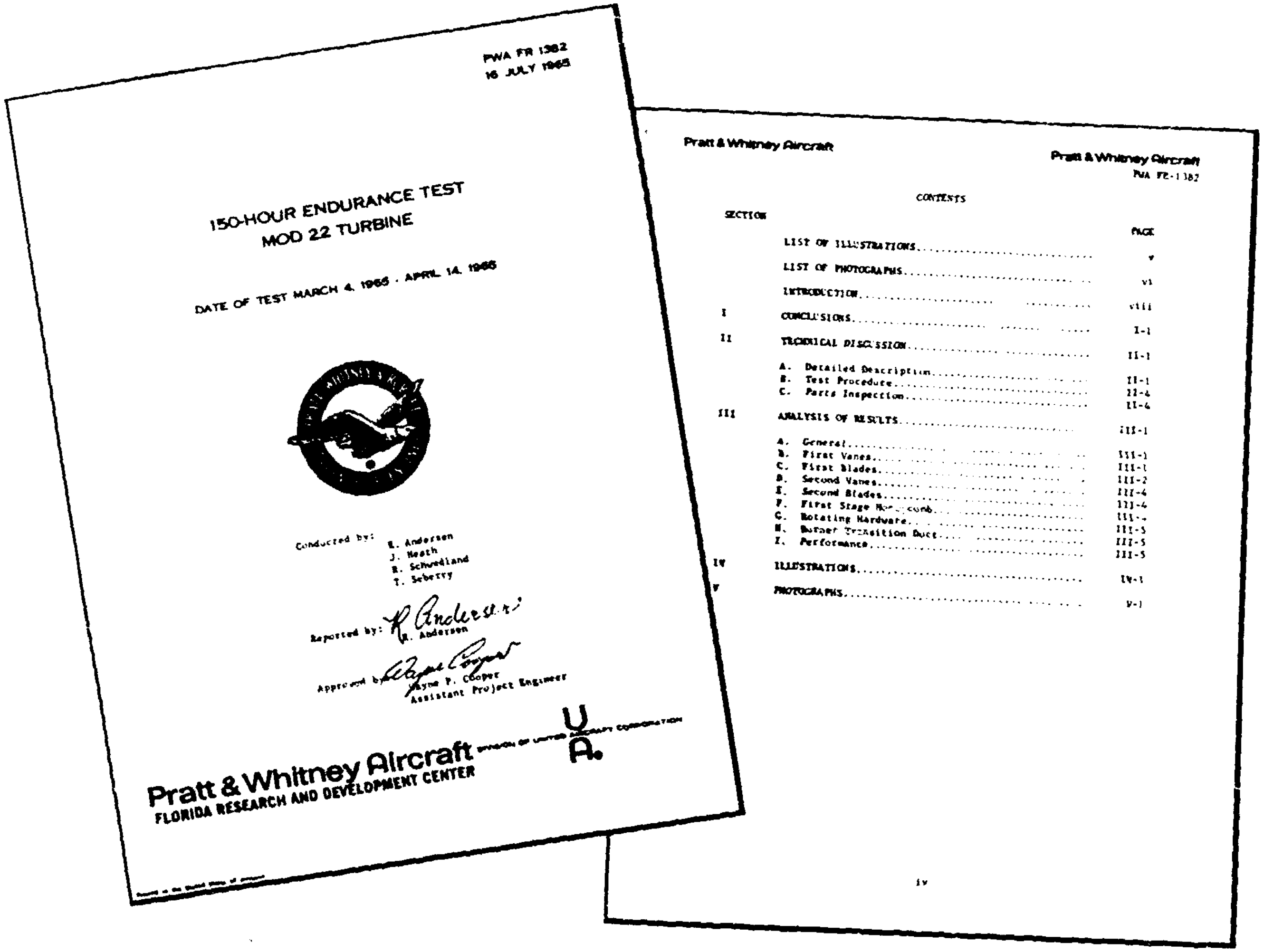
JTF17A-20 2nd Stage Vane



Pratt & Whitney Aircraft

63111
FD 13992

Exhibit K. Sample Pages, Heat Transfer Test



PWA FR 1382
16 JULY 1965

150-HOUR ENDURANCE TEST
MOD 22 TURBINE

DATE OF TEST MARCH 4, 1965 - APRIL 14, 1965

Conducted by: R. Andersen
J. Heath
R. Schwedland
T. Seberry

Reported by: R. Andersen
R. Andersen

Approved by: Wayne P. Cooper
Wayne P. Cooper
Assistant Project Engineer

Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION
FLORIDA RESEARCH AND DEVELOPMENT CENTER

Pratt & Whitney Aircraft

Pratt & Whitney Aircraft
PWA FR-1382

CONTENTS

iv

FD 17819
EA

Exhibit L. Sample Pages, 150-Hour Endurance Test Report, Mod 22 Turbine

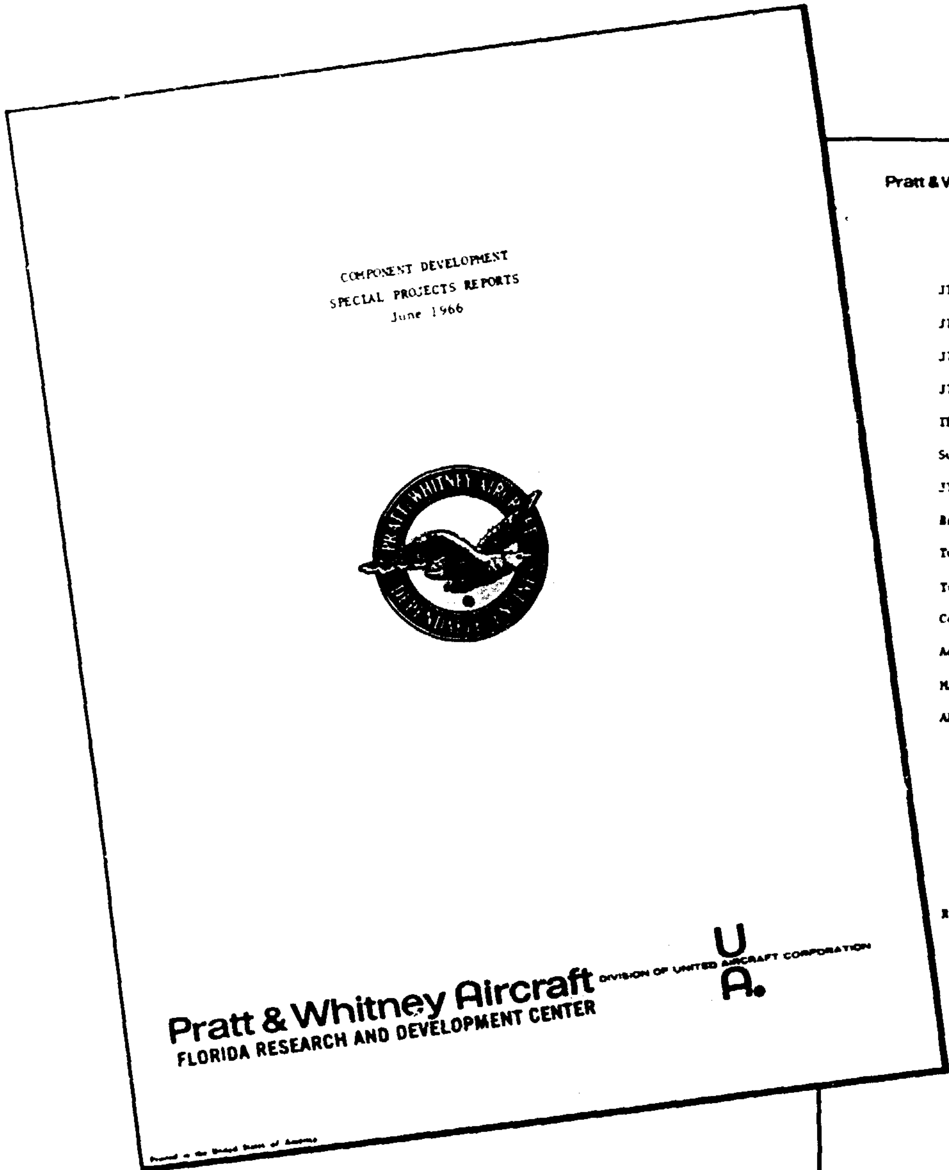
MORNING STATUS REPORT
SST

March 22, 1966

Rig	Location	Program	Status
FAN			
F-25005	X-204	Performance run with build 5 1st blades and redesign I 2nd blades	Decision was made yesterday to install build 5 1st blades with the build 8 drooped splitter to try to get high speed flow back up. Rig should run Thursday. Rig total time 397.08 hours.
HIGH COMPRESSOR			
F-35010	C-3	Engine surge margin investigation	Ran rig with distortion generator in inlet. Had no significant effect on comp. perf. stress picture with resultant distortion pattern. Pattern is approx. what engine would see at 90% $N/\sqrt{\theta}$. We need more severe distortion at 100%. No mechanical problems with the rig. Ran several speed lines at 3 vane settings. In all but one data appeared to duplicate last build. Reviewing data to determine cause of "odd" points on one line. No significant change to surge line was accomplished at the three vane setting tested. Ran 3 speed lines with unthrottled inlet to further check Reynold's number effects. None apparent. Surge stresses were 60-70K psi max. in 3rd and 5th blades. Total run time 33.52. Build 3 time 4.83. 3/21 run time 4.83. EHT 2nd shift.
MAIN COMBUSTOR			
X-202	A-1	Investigate causes for hot streaks in the JT4	Ran yesterday and still had the 4 hot spots. Opening overboard bleed hole on the JT4 diffuser helped. The diffuser adapter is rotated 9° to change strut positions and a run is expected this shift
F-35011	A-11	120-deg segment primary combustor test	Changing the JT3 engine.
TURBINE			
F-35018	Assembly	Heat transfer (JTF17 1st blade)	Rig was pulled from stand. Teardown inspection and data analysis of 3 chamber blade data in process.
F-30180	Assembly	Heat transfer (B-20 1st blade)	Built with 3 wall blade. Ready to go to test.
F-20709	B-2-8	Heat transfer (B-20 1st vane)	Plan to run Thursday with modified down-stream radiation shield and revised method of T.E. pressure measurement.

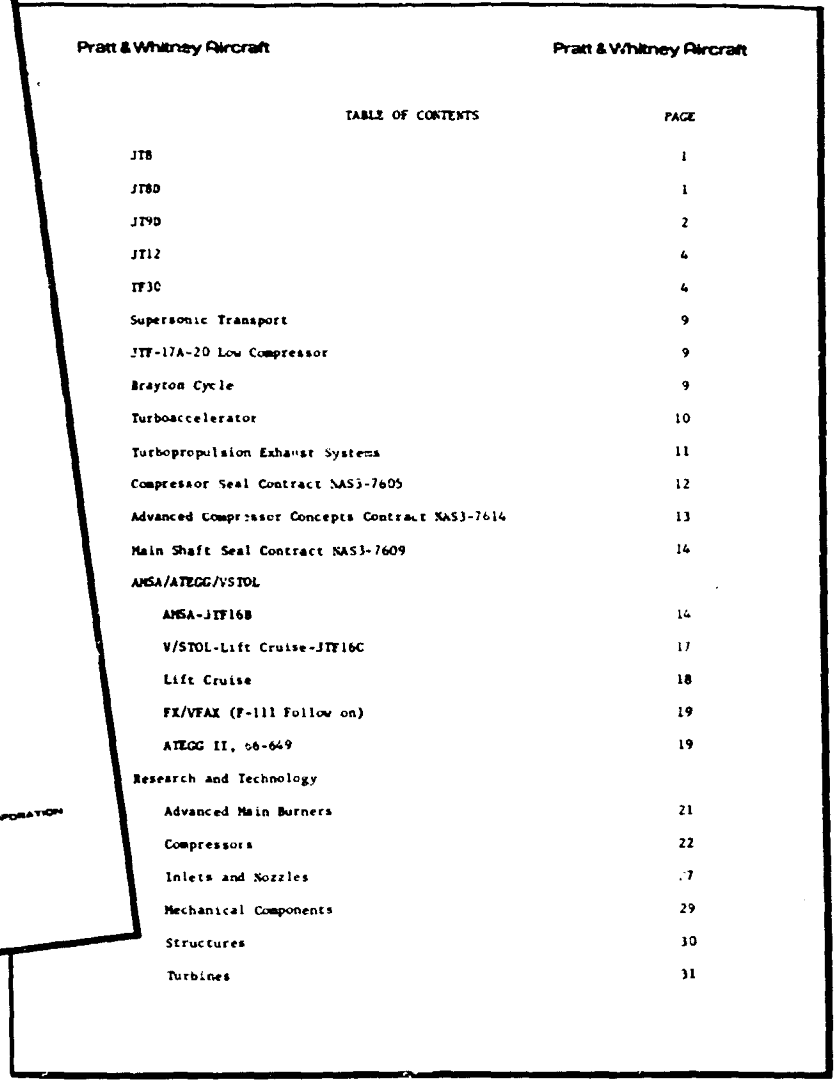
Exhibit M. Sample of Morning Status Report, SST FD 17906
EA

FD 17907
EA



COMPONENT DEVELOPMENT
SPECIAL PROJECTS REPORTS
June 1966

Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION
FLORIDA RESEARCH AND DEVELOPMENT CENTER



Pratt & Whitney Aircraft Pratt & Whitney Aircraft

TABLE OF CONTENTS

Exhibit N. Sample Pages From Progress Report of Special Projects, Component Group

REPORT F
PRODUCT ASSURANCE

SECTION I
MAINTAINABILITY PROGRAM

A. OBJECTIVE

The Maintainability Program objective is to assure the development of the highest attainable maintainability for the JTF17 engine in the supersonic transport during airline operation.

B. SUMMARY

This JTF17 Maintainability Program Plan contains Pratt & Whitney Aircraft's commercially oriented approach to ensuring a maintainable SST powerplant from design inception through operational service. The plan describes the organizational structure of the support groups which will contribute to the coordinated maintainability effort. The program is specifically tailored for the JTF17 engine. Maintainability is a key to safety and economical operation. The high capital investment in SST equipment makes a high daily utilization rate a requirement, and makes it imperative that down time and maintenance manhours per engine flight hour be held to a minimum. Accordingly, a concentrated effort was initiated at JTF17 design inception to assure that all phases of maintenance be given careful consideration. Emphasis was placed in the following areas:

- Provide comprehensive inspection and monitoring provisions with engine installed in the airplane.
- Design hardware to reduce, simplify or eliminate maintenance actions.
- Design for maximum installed repair and replacement capability.
- Establish comprehensive repair procedures for shop and overhaul to extend parts life.
- Maximum utilization of unitized component construction. This feature lends itself to the Turbine Engine Reliability Program (TERP), which permits engines to age in service without fixed overhaul time limits.

The JTF17 powerplant utilizes a new design conception -- Unitized Construction. Unitized Construction provides a high degree of component accessibility, reduces maintenance turnaround time, thereby minimizing aircraft downtime. The following are several of the major maintainability features designed into the JTF17 engine:

- Strategically located provisions for borescope inspection of the compressor, combustion and turbine sections. The extension or elimination of combustion chamber area inspection may be possible based on borescope inspection results made during transit and equalized inspection periods.

- Front and rear radioisotope inspection provisions.

- Oil system chip detection provisions on the outside of the engine.

- Removal and replacement of the fan rotor and stator assembly without disturbing the inlet case and turbine.

- Removal and replacement of the duct heater and reverser-suppressor aft of the rear mount ring.

- Externally mounted oil scavenge pumps.

- A shorter, more powerful fan unit permits overhanging the rotor beyond the front bearing. This eliminates the inlet case structure and the attendant need for anti-icing of inlet guide vanes.

C. MAINTAINABILITY ORGANIZATION

JTF17 Maintainability will be the responsibility of the Chief, Maintainability and Human Engineering, who will report through the JTF17 Product Assurance Manager to the JTF17 Program Manager.

The Product Assurance organization will control the related disciplines of maintainability, reliability, safety, quality assurance, human engineering, value engineering and standardization. It is well suited to coordinating the airframe, engine, airlines and Federal Aviation Agency requirements in these areas. The assignment of an individual responsible for each discipline will improve communications and centralize responsibility. The Product Assurance organization is described and illustrated in Volume V, Report I.

The Chief, Maintainability and Human Engineering, directs all tasks described in the Maintainability Program Plan to assure attainment of the JTF17 maintainability objectives. He is responsible for coordinating maintainability interface functions with airframe contractors, the Federal Aviation Agency, and the Airlines. The JTF17 maintainability organizational structure is outlined in figure 1. Specific responsibilities of the Maintainability Support Groups are as follows:

1. Product Support Group - Provide Field Service experience and technical assistance pertaining to maintenance and overhaul procedures currently used by the commercial carriers. Supply reports of engine in-service data for analysis. Design and develop the required ground support equipment.

2. Design Maintainability Group - Provide Design Department with the requirements and philosophy to implement the incorporation of maintainability features. Control the incorporation of maintainability features through documented design reviews and tradeoff studies.

3. Development Maintainability Group - Extend engine parts life through development of realistic wear limits and parts repairs, and establish maintainability tests and demonstration requirements.

4. Statistical Group - Provide a staff consulting service pertaining to JTF17 performance and engine-airframe statistics.

5. Assembly and Test - Provide information pertaining to assembly-disassembly problems and techniques, maintenance actions, and inspection capabilities.

6. Quality Assurance - Develop engine condition inspection equipment and techniques. Extensive work is being done on Radiography and Borescope equipment.

7. Purchasing Department - Provide specific Maintainability Requirements governing vendor supplied controls, accessories and components through Purchase Order agreements.

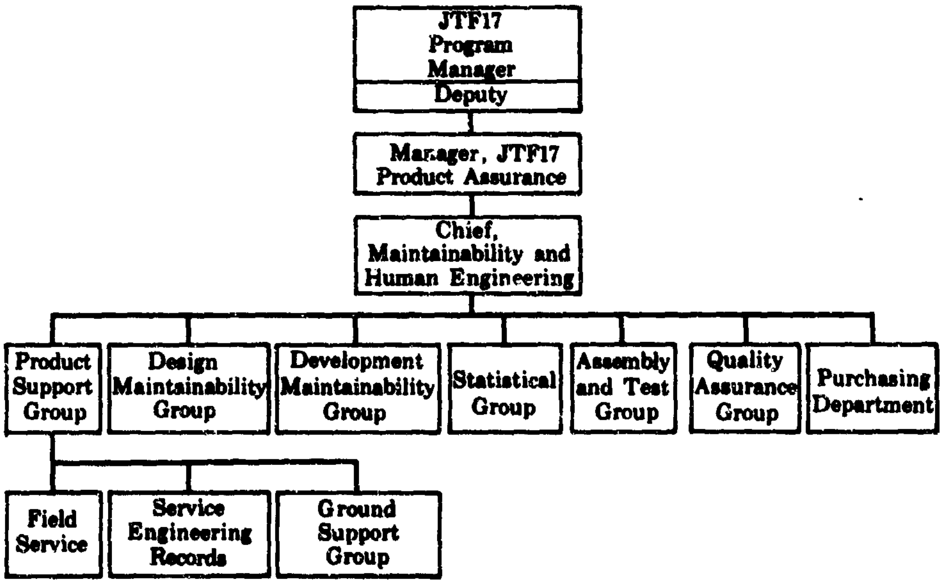


Figure 1. JTF17 Maintainability Organization FD 17558 FI

D. QUALITATIVE MAINTAINABILITY OBJECTIVES

In accordance with the objectives of the Maintainability Plan, consideration has been given to the environmental conditions in which the engine will be operated and maintained in the establishment of the qualitative objectives.

Specific qualitative design objectives have been established during Phase II-C for the JTF17 engine, which will optimize maintenance requirements and ensure low overall maintenance costs.

These objectives are:

- Minimize maintenance task complexity.
- Eliminate the possibility of maintenance errors.
- Ensure accessibility of components requiring inspection, servicing, or other maintenance action.
- Provide for maximum safety of personnel and maximum protection for the engine.
- Minimize spare parts inventory by the use of standard items; multiple use of common parts when possible and providing for a high level of interchange between various series or engine models.
- Minimize skills and training required by maintenance personnel.
- Minimize ground support equipment (GSE) required to support all phases of engine maintenance.

To ensure optimum airline maintainability, the following supplemental objectives have been incorporated to allow for additional troubleshooting and maintenance capability:

- Selection and development of engine parameters and sensors required for the Airborne Integrated Data System (AIDS).
- Develop the extent to which engine performance and associated system equipment can be verified without the need for external support equipment.
- Provide maintenance features that ensure optimum fault location, fault isolation, checkout verification capability, disassembly and reassembly.
- Develop a maximum repair capability for all engine parts and components prior to SST operational service.
- Respond to the intent of Federal Aviation Agency Advisory Circular 120-17, "Handbook for Maintenance Control by Reliability Methods," by developing maintenance and inspection techniques to enhance the Turbine Engine Reliability Program (TERP).
- Continue to evaluate sonic analysis techniques to determine engine condition as an aid to installed maintenance.

The attainment of these objectives will require the best possible coordination and communication between Pratt & Whitney Aircraft, the airframe contractor, the airlines and the Federal Aviation Agency. The Maintainability Plan includes provisions for frequent FAA/Airline and airframe contractor reviews, to ensure the attainment of these goals.

E. QUANTITATIVE MAINTAINABILITY GOALS

The Maintainability Index for the JTF17 engine will be estimated during Phase III. It will indicate the maintenance manhours per engine flight hour for a mature engine in commercial service.

Quantitative maintainability goals were established during Phase II-C to be employed in the development of maintenance manhour requirements, frequency of maintenance actions, and for the establishment of the predicted mature Maintainability Index.

Engine maturity is attained when failure rates for the engine become relatively low and stable over a significant period of time. Maturity of the JTF17 engine will be attained during the fourth year of commercial service as described in the Reliability Plan Section II of Report F.

In establishing the Maintainability Index, only direct maintenance manhours employed in the following scheduled maintenance functions will be considered:

- Scheduled Service Check, Enroute Check, and Turnaround Check type inspection
- Scheduled minor intermediate inspections with cowl open
- Scheduled major intermediate inspections with cowl open.

Maintenance functions excluded from the determination of the total maintainability index are:

- Fuel Servicing
- Engine Overhaul
- All maintenance actions resulting from failures or discrepancies that are nonchargeable to the engine
- Compliance with directives, bulletins, and engineering orders when related to upgraded engine performance or changes in specification requirements
- Maintenance actions required to gain access to the engine or removal and installation of engine from aircraft
- Actions associated with airframe supplied QEC equipment.

During Phase II-C, the following predicted quantitative maintainability goals were established (table 1) for removal and replacement of components:

Table 1. JTF17 Maintenance Goals

Item	Elapsed Hours*	Manhours
Fuel turbopump (duct-heater)	0.5	0.5
Exciter (main and duct)	0.5	0.5
Main gearbox	11.0	21.5
Hydraulic pump	0.5	0.5
Main fuel pump	0.5	1.0
Unitized fuel control	0.5	1.0
Fuel flow meter	0.3	0.3
Main dump valve	0.5	0.5
Tach generator (each)	0.25	0.25
Drain valves (Zone I and Zone II)	0.5	0.5
Oil pump gearbox and oil tank	3.0	6.0
Combined fuel oil coolers	1.0	2.5
Turbopump controller	0.5	0.5
Fuel primary bypass valve (duct-heater)	1.0	1.0
Power takeoff gearbox	0.5	0.5
Duct burner Zone I nozzles	3.5	7.0
Reverser-Suppressor actuators	1.0	2.5
Duct nozzle actuators	2.0	7.0
Duct heater	5.5	16.0
Breather pressurizing valve	0.25	0.25
Main fuel nozzles	3.0	10.0
Gas generator bleed valves	7.0	27.0
Gas generator turbine exhaust Thermocouples set	1.0	1.0
Main engine igniters	0.5	0.5
Duct burner igniters	0.25	0.25
Turbine exhaust harness	2.5	4.5
Duct heater burner	3.0	8.0
No. 2 bearing	26.5	95.0
Hot section in place	6.0	20.5
1st stage turbine nozzle	8.5	24.0
Turbine exhaust case	9.5	18.0
Reverser-Suppressor	2.0	4.0
No. 4 bearing	3.5	3.5
No. 1 bearing	7.0	12.5
Low turbine	9.5	31.0
High turbine	13.5	38.0
No. 3 bearing	19.0	45.5
Primary combustor	7.0	21.5
Fan section assembly	3.0	5.0
1st stage fan blades	5.0	6.5

* Does not include time required for removal of airframe hardware to gain access to engine.

The listed maintenance goals represent values that have been established by:

- Review of Maintenance tasks by layouts, assembly drawings, and mockups
- Assembly and disassembly of experimental JTF17 engines
- Time studies of current commercial turbine engine assembly and disassembly procedures
- Time studies of production Mach 3 J58 maintenance and overhaul procedures.

During Phase III when the reliability failure rates have been established, the evaluation of the manhours required to perform a specific task in conjunction with the reliability failure rate will determine those areas requiring the maximum maintainability effort. Other manhour requirements will be continually evaluated so that opportunities to increase maintainability will not be overlooked.

F. AIRLINE MAINTENANCE PLAN

An engine maintenance support concept has been established that ensures an efficient system of maintainability from inspection through overhaul. Representative levels of airline inspection and maintenance requirements are given in the following paragraphs.

1. Inspection - Engine Installed

- Transit Inspection - Enroute Check
- Terminal Inspection - Turnaround
- Phased Inspection - Periodic

The JTF17 design permits airline inspection requirements to be accomplished with the engine installed in the airframe. Optimization of these requirements will be satisfied by engine and airframe contractor coordination and interface compatibility review. The scheduled inspection intervals will be established to coincide with the inspection cycle of the aircraft.

a. Transit Inspection - Cowl Closed

Inspection of the inlet, exhaust, duct-heater and reverser-suppressor sections is required. All sections are readily visible for inspection. Foreign object damage or other abnormal conditions will be readily detectable.

b. Terminal Inspection - Cowl Closed

Terminal inspection requirements include the transit inspection requirements. Terminal inspection also requires an oil level check and an ignition check. The JTF17 engine design has provisions for remote oil level indications and servicing.

c. Phased Inspection - Cowl Open

Phased inspection requirements include the terminal inspection requirements. In addition, at this level of inspection all external tubing and electrical wiring are checked for security of mounting and evidence of leakage or chafing. The inlet, exhaust and accessory gearbox areas are given special attention. Visible engine flange joints are inspected for evidence of leakage or distortion which would be indicative of internal discrepancies. Fuel and oil filters are removed and cleaned or replaced. Borescope inspection of the high compressor rotors, main burner area and turbine rotors can be accomplished at this time.

2. Light Maintenance - Engine Installed

Unscheduled (corrective) light maintenance usually involves troubleshooting tasks and the removal and replacement of accessories. Engine accessories are readily accessible and are provided with quick-connect-disconnect mounting features thereby reducing removal and replacement time.

Light maintenance will also encompass troubleshooting of the exhaust temperature system, and the removal, replacement, or repair of the accessory drive gearboxes, external oil scavenge pumps and associated external lubrication system components and tubing. Additionally light maintenance repair capability will be developed for the duct heater and the reverser-suppressor.

3. Heavy Maintenance - Engine Installed

The need for unscheduled Engine Heavy Maintenance (EHM) capability is recognized. The JTF17 design provides the capability for installed Engine Heavy Maintenance tasks as follows:

- Combustion Chamber Area inspection and repair
- Major component removal and repair

Combustion Chamber Area Inspection (CAI) will be facilitated by design considerations that allow access to combustion-turbine area with minimum disassembly. Borescope of the combustion-turbine area will determine the need for CAI. Removal of the primary burner case allows for inspection and repair or replacement of items such as the segmented annular burner liners, and 1st-stage vane.

Unitized construction of the engine permits repair, removal or replacement of major subassemblies as separate units without complete disassembly. This design feature permits removal and replacement of items such as fan stages, turbine exhaust case, turbine assemblies and combustion area components. Additionally, the No. 1, No. 2 and No. 4 bearings and seal assemblies can be removed and replaced.

4. Heavy Maintenance - Engine Removed

During Engine Heavy Maintenance, the JTF17 engine can be disassembled and assembled in the horizontal or vertical position or a combination of

these positions. Design emphasis was placed on the use of unitized component construction. This feature simplifies engine assembly and disassembly and makes remote areas of the engine more accessible.

5. Overhaul and Test

Preliminary Airline system integration studies reveal:

- JTF17 maintainability design features have minimized the need for new overhaul techniques.
- Existing overhaul facilities and equipment will require minimum alteration.
- Personnel skill levels unaffected.
- Modifications to existing Ground Support Equipment (GSE) will minimize costs associated with the acquistion of new and additional GSE.
- Engine test facilities capable of handling the JT9D engine will accommodate the JTF17 engine.

6. Maintainability Features

Specific details pertaining to JTF17 inspection, maintenance and overhaul in support of this Airline Maintenance Plan will be found in Exhibit A.

G. MAINTAINABILITY ASSURANCE

To assist in the achievement of the maintainability objectives and goals outlined previously, the following procedures will be employed during the SST program:

1. Design Checklist

The JTF17 Design Maintainability and Human Engineering Checklist, FTDM-208, provides the basic philosophy of maintainability and pinpoints the important design precautions and objectives to assure maintainability. This checklist outlines general engine design guidelines, such as providing for:

- Ease of engine assembly and disassembly.
- Ease of inspection.
- Assembly foolproofing.
- Component accessibility.

Consideration is given to items such as balancing of rotating parts, bracketing, gears and splines, bearings, seals, and coating and plating techniques to assure optimum maintainability. This checklist is continuously revised by the Chief, Maintainability, to reflect the latest guidelines for the incorporation of maintainability into design.

2. Integration of Service Experience

- Conferences will be scheduled on a continuing basis with airline, FAA, and airframe personnel to review the JTF17 engine design and to further the improvement of engine maintainability.

- Data obtained during engine development will be continually reviewed.

- During the ground test, flight test and certification phase of the SST program, Pratt & Whitney Aircraft will establish a Field Service and Flight Operations Engineering program at the test sites. Details outlining program establishment will be found in the Product Support Plan Section VI of Report F.

- Design experience and service operational data on current engines will be reviewed for their maintainability implications.

Pratt & Whitney Field Service Representatives, presently stationed at world-wide commercial and military activities, report regularly on all facets of operation, maintenance and overhaul. These inputs are supplemented by inflight operational data obtained by the Flight Operations Engineering Group during frequent liaison with commercial operators. Their reports are submitted to a Technical Data Staff at Pratt & Whitney Aircraft, which assures prompt distribution of these reports to the Chief, Maintainability, and other groups concerned.

The Service Engineering Records group analyzes, catagorizes and records engine operation, maintenance and overhaul experience as reported by our Field Representative and other airline and military sources. This information is stored by means of electronic data processing equipment and issued in reports and summaries of operating and reliability histories. The analysis of this in-service data by the Chief, Maintainability and other groups is a major factor in determining the maintainability features required in the engine design.

The Data Flow Chart, figure 2, delineates the integration of data from supporting groups into the total Maintainability Program.

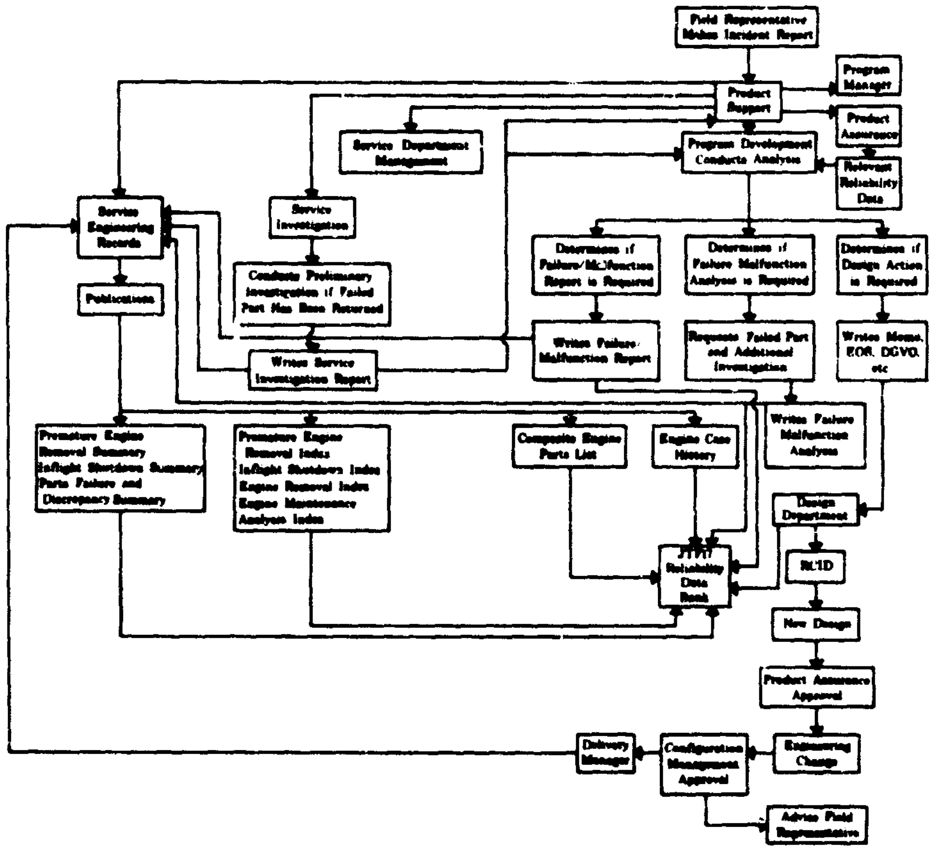


Figure 2. JTF17 Service Problem Information Flow Path FD 17520 FI

3. Design Review

The Maintainability Program of the JTF17 engine design will be guided by design reviews. During Phase III, Pratt & Whitney Aircraft will continue the basic procedure of design reviews employed for Phase II-C.

a. Review Procedures

The Design Maintainability Engineers, under the direction of the Chief, Maintainability, perform a continuous review of the JTF17 design for Maintainability. The procedures employed are a part of the closed-loop maintainability assurance system shown in figure 3. The system ensures maintainability inputs to the design requirements, provides for approval of all layouts by the Chief, Maintainability or his delegate, and assures that maintainability requirements will be a part of any future redesigns.

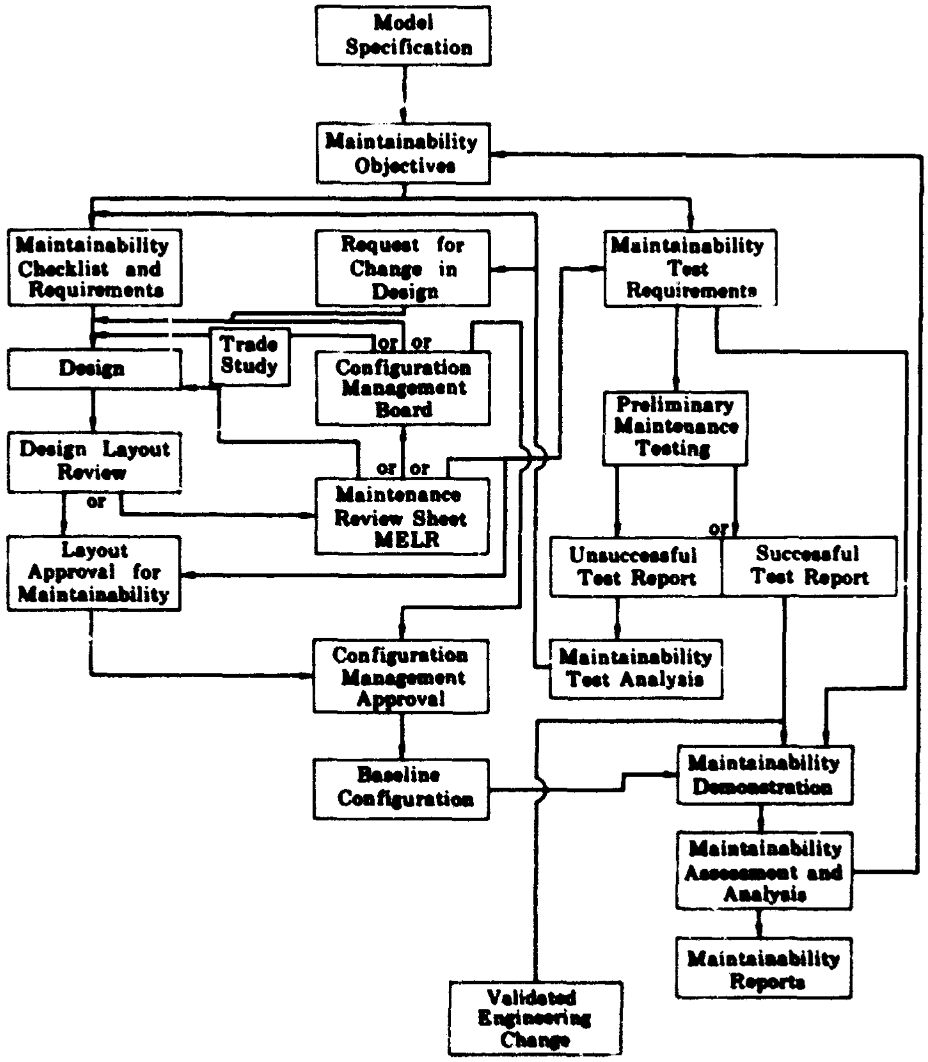


Figure 3. Maintainability Flow Chart FD 17539 FI

The following briefly describes the system. The reader is referred to the Configuration Management Plan, Volume V, Report C, for more detail.

1. Maintainability Goals and Objectives are established in accordance with specification requirements and overall program objectives and approved by the Program Manager.

2. Maintainability Test Requirements are prepared by the Development Maintainability Group and approved by the Chief, Maintainability.

3. Design requirements are prepared by the Design Maintainability Group and approved by the Chief, Maintainability.

4. All components, subassemblies and parts are designed using the Maintainability Checklist as a guide and in accordance with the maintainability requirements.

5. The design layout is reviewed by the Design Maintainability Engineer for conformance with the Maintainability Checklist, and the maintainability requirements.

6. The Chief, Maintainability, or his delegate, approves the layout by signing. If the layout is not approved, a Maintainability Engineering Layout Review (MELR) sheet (figure 4) (PWA 10696D) is prepared. The MELR will state the objections and requests:

   a. Additional analysis and/or study, or a minor change in design (in which case the layout is returned to the designer)

   b. Specific maintainability tests be added to the Maintainability Test Requirements (following which the layout is approved)

   c. A major change in design (which is referred to the Configuration Management Board for review).

   The MELR must be approved by the Chief, Maintainability.

MAINTAINABILITY ENGINEERING LAYOUT REVIEW

Layout No. ____________ Title ______________________________

Designer ____________________ Review Date ____________ By: ____________

Item	Remarks

Follow Up

Item	Date	Results

PWA 10696D

Figure 4. Maintainability Engineering Layout Review

FI

7. The Configuration Management Board reviews the MELR, the layout, and the design tradeoff studies and

    a. Requests a new tradeoff study

    b. Directs a major change in design

    c. Rejects the MELR and directs the Design Maintainability Engineer to approve the layout.

Following layout approval (or Engineering Change approval) by the Chief, Maintainability or his delegate, the layout (or Engineering Change) is approved in accordance with the approval system described in the Configuration Management Plan.

b. Engineering Change Control

All engineering design changes will be reviewed by the Chief, Maintainability, the Design Maintainability Group, and the Field Service Group prior to sign-off approval for their effect on established maintainability requirements. If installation compatibility is affected, the proposed changes are submitted to the Airframe Contractor through the Field Survey Procedure, which is outlined in the Configuration Management Plan. Following signed approval by the Airframe Contractor, the engine assembly drawings, installation drawings and the engine mockup will be revised accordingly.

c. Pratt & Whitney Aircraft Design Review Board

To assure that the benefits from our past experience are reflected in the design and development of the JTF17 engine, P&WA will hold P&WA Design Reviews by the P&WA Design Review Board. This review will be in addition to the procedures discussed above.

The P&WA Design Review Board made up of experienced Program Managers and other senior Development Engineers from FRDC and East Hartford will meet periodically to a schedule established on the basis of major design accomplishments. The schedule for these reviews will be incorporated in the Configuration Management Plan in Phase III.

The Board's principal function in Phase III as it was in Phase II-C will be to contribute suggested solutions to SST development problems, and to review the design to assure that problems that arise or have been previously experienced on other programs are not inadvertently designed into the SST. The Board's activities will, therefore, serve as a check to assure that the Design Review Procedures carried out on a continuing basis have not overlooked any of P&WA's related experience on other development and production programs.

d. Major Program Reviews

Final assurance to preclude the omission of a valid design consideration during the periodic Pratt & Whitney Aircraft Design Reviews or Design Review Procedures will be attained at these Major Program Reviews attended by FAA/Airframe and Airlines maintainability personnel.

4. Maintainability Demonstration

Pratt & Whitney Aircraft will conduct a JTF17 maintainability demonstration for FAA, Airline and airframe manufacturing personnel to:

1. Verify the attainment of the predicted qualitative and quantitative maintainability goals.

2. Evaluate the effectiveness of maintenance tooling and allied GSE.

3. Show the quantity and skill level of personnel required to perform various maintenance functions.

4. Provide for an initial review of the engine maintenance manuals under conditions typical of an airline maintenance environment.

5. Review with the participants all aspects of JTF17 maintainability, product support, facility planning, engine overhaul, etc.

The tasks to be accomplished at this demonstration are:

1. Demonstration of transit, terminal, and equalized maintenance requirements, including use of borescope and radioisotope.

2. Performance of a typical Combustion Chamber Area hot section inspection (CAI).

3. Complete engine heavy maintenance disassembly and reassembly.

The scheduling of this demonstration will be dependent upon engine availability and coordination with the Airframe Contractor and the airlines. This demonstration will be made available to the foreign carriers at a site of their selection, if desired. Additionally, Pratt & Whitney Aircraft will assist the airframe contractor during the performance of the airframe/engine system maintainability demonstration.

5. Maintainability Interface

Airframe - Engine Interface

Pratt & Whitney Aircraft recognizes that it is necessary and in the best interest of the SST Program to coordinate and exchange maintainability analysis data and information with the airframe manufacturer. Maintainability planning agreements have been included in the Interface Compatibility Agreement negotiated with the airframe contractor for Phase III. The agreements set forth the understanding of the parties with regard to their responsibilities for total system maintainability. Coordination in accordance with the agreement will continue in Phase III. The reader is referred for details to copies of the agreements that are included in the airframe contractor's proposal.

6. Subcontractor Maintainability

Maintainability characteristics of vendor-supplied items are subject to review and approval by the Chief, Maintainability and the Project Engineer assigned to the development of the unit. These items are subject to the same maintainability assurance procedures applicable to the basic engine.

Periodic review and progress reports from subcontractors will be employed to assure that both qualitative and quantitative maintainability requirements are achieved. Details of vendor maintainability requirements are outlined in Volume III, Report B, Section III.

7. Mockup Maintainability Demonstration

The full-scale engine mockup will provide a check point for assurance of design objectives and will facilitate evaluation of inspection, maintenance, overhaul and envelope clearance requirements. As the exterior configuration of the engine becomes finalized, full-scale Class III mockups will be fabricated for final installation design work. The mockup, which is an exact representation of the external details of the released engine design, will be reviewed for installation and external maintainability features. Based on this review, relocation of external components and rerouting of external tubing will be recommended whenever accessibility can be improved.

In addition, two- and three-dimensional mockups have been prepared for evaluation of assembly and disassembly procedures. These models are used in discussing maintenance tasks and maintainability features with FAA, Airline and Airframe personnel.

Details outlining the engine mockup will be found in the Installation and Inlet System Compatibility Plan Volume III, Report D.

8. Engine Parts Repair

Pratt & Whitney Aircraft has established the requirement for a maximum repair capability for all engine parts and components. The Chief, Maintainability, in coordination with the Development Maintainability Group, is responsible for the accomplishment of this task. Studies of specific engine repair requirements and procedures presently being accomplished on current commercial engines, the Mach 3 J58 engines, and the JTF17 development engine are being conducted. Repair procedures will be developed during the JTF17 engine development program to ensure an initial repair capability equal to or greater than that which exists for current Pratt & Whitney Aircraft engines. The goal of this engine parts repair program is to develop and publish a complete Overhaul Manual Repair Section concurrent with the delivery of the initial production engine for the flight test program.

9. Airborne Integrated Data System

Pratt & Whitney Aircraft is responsive to the need for an Airborne Integrated Data System (AIDS) in the SST aircraft. Interface action relative to the selection and development of initial engine parameters

has already commenced with the airframe contractors. The ultimate goal is to ensure an airborne maintenance analysis system of minimum complexity and maximum reliability capable of acquiring and presenting accurate engine performance and corrective/preventive maintenance data. JTF17 engines will incorporate airframe/engine approved instrumentation provisions designed to provide for the attainment of this goal.

Pratt & Whitney Aircraft will be responsible for including provisions to adapt the engine to the Airborne Integrated Data System (AIDS). Necessary action will include:

1. Definition of engine and engine component parameters.

2. Definition of data sampling rates

3. Establishment of functional relationships or correlation between the behavior of different but related engine parameters, i.e., vibration and compressor rpm.

4. Definition of engine and engine component end point instrumentation requirements.

5. Development and testing of instrumentation supplied by Pratt & Whitney Aircraft

6. Testing of any airframe supplied transmitters and transducers, as required for the above, including the necessary attaching features and wiring harnesses.

7. Establishment of engine connecting points compatible in position and form to the airframe.

The determination of end point AIDS instrumentation required for engine measurements and fault isolation will be achieved by agreement between the airframe contractor and Pratt & Whitney Aircraft. Experience on engine instrumentation systems will be accumulated by endurance testing of sensing devices during Pratt & Whitney Aircraft's normal full-scale engine development tests.

H. TURBINE ENGINE RELIABILITY PROGRAM

Pratt & Whitney Aircraft is completely responsive to the development of the Turbine Engine Reliability Program (TERP) as outlined in the FAA Advisory Circular 120-17.

This advisory Circular encourages the commercial airlines to initiate a more rapid engine TBO growth program by examining and exploring their individual capabilities in order to develop a realistic set of engine reliability controls that integrate established maintenance controls with current operating experience.

The TERP Program allows the commercial airlines to operate turbojet engines in service without fixed TBO limits, during which time the engine reliability trends are explored and evaluated as the engine ages in daily service operation.

Reliability data of the nature described as follows is obtained during in-service operation.

1. Engine in-flight shutdown rates and causes

2. Engine premature removal rates and causes

3. Examination and evaluation of engines prematurely removed

4. Examination and evaluation of engines removed for periodic inspections and engine heavy maintenance as well as overhaul.

The commercial airlines have long recognized that short-life parts in the turbojet engines have in the past played an all too dominant role toward the determination of fixed engine TBO's. Under the TERP maintenance concept, engines are scheduled into the Engine Heavy Maintenance (EHM) Shop for inspection, rework, repair or replacement of these short-life parts. The frequency of the scheduling of engines into the EHM Shop is predicated by a thorough study of parts-time reliability relationship of these short-life parts. Parts condition improvements result in an increase in the EHM intervals. The EHM Program as related to TERP allows the exploration of engine long-life parts on a far more rapid schedule while still maintaining a high degree of engine reliability. By the full implementation of a TERP Program it seems reasonable to anticipate that the reliability of the JTF17 engine may be attained without the need of a fixed TBO limit. Studies related to the parts aging reliability aspects will determine the extent and frequency of line maintenance inspections as well as scheduled engine removals for parts repair or replacement at EHM.

The end result of the TERP maintenance concept is that the EHM Program allows TBO's to develop far more rapidly while maintaining a high degree of reliability thereby realizing a considerable saving in manhours and material costs.

The unitized construction and EHM which will be developed and demonstrated on the JTF17 engine lends itself particularly to the Turbine Engine Reliability Program. In anticipating that the initial JTF17 TBO time will be fixed at 600 hours, it is expected that the TBO growth will be realized over a shorter accumulation of operating hours than that which has been attained by the initial commercial Turbojet engines through the full implementation of the Turbine Engine Reliability Program into the JTF17 maintenance concept.

Exhibit A lists JTF17 maintainability features that are responsive to this requirement.

I. DOCUMENTATION OF MAINTAINABILITY REQUESTS

An effective maintainability documentation system has been established to ensure a complete systematic program of analytical reviews, design tradeoff studies, and written detailed reports on the acceptance or rejection of a specific feature.

A specific maintainability request will originate from the Chief, Maintainability, or the design Maintainability Engineer, as a result of an analysis of data supplied by the various maintainability support groups (see figure 1). This will be a written memo requesting a tradeoff study, a maintainability design revision, a design suggestion, or a maintenance requirement. The memo will be sent to the cognizant Design Chief for engine design action, with copies for the various maintainability support groups to provide a closed loop system of information on all active maintenance requests.

After the proposed feature has been reviewed regarding design reliability, maintainability, value, weight, cost, human engineering, safety, airframe interface, and possible effect on engine design integrity or performance, the request is either accepted or rejected and submitted.

Acceptance of the proposed feature is documented by way of a job request to initiate a design layout. A record of the job request number and the design layout number is returned to the Design Maintainability Group along with the status of action to the proposed request. Further followup is then performed by the Design Maintainability Group to ensure the completion and incorporation of the maintenance feature. Upon completion of the layout, the Design Maintainability Group will review and approve it. An Experimental Release or Request for Engineering Change is then required to incorporate the feature into the prototype or production engine. Refer to Configuration Management Plan for procedures. A review of the engineering changes are also made to assure that the intent of the original request has been met.

Rejection of the proposed feature requires a comprehensive written description of the tradeoff studies that were performed, the particular engine feature which is affected and to the exact extent. Final review and approval of the rejection is made by the Chief of Maintainability. For a flow chart of documentation, see figure 5.

A central file of all maintainability documentation will be located and maintained by the Design Maintainability Group. Figure 6 indicates the various forms of documented data that are integrated into the files.

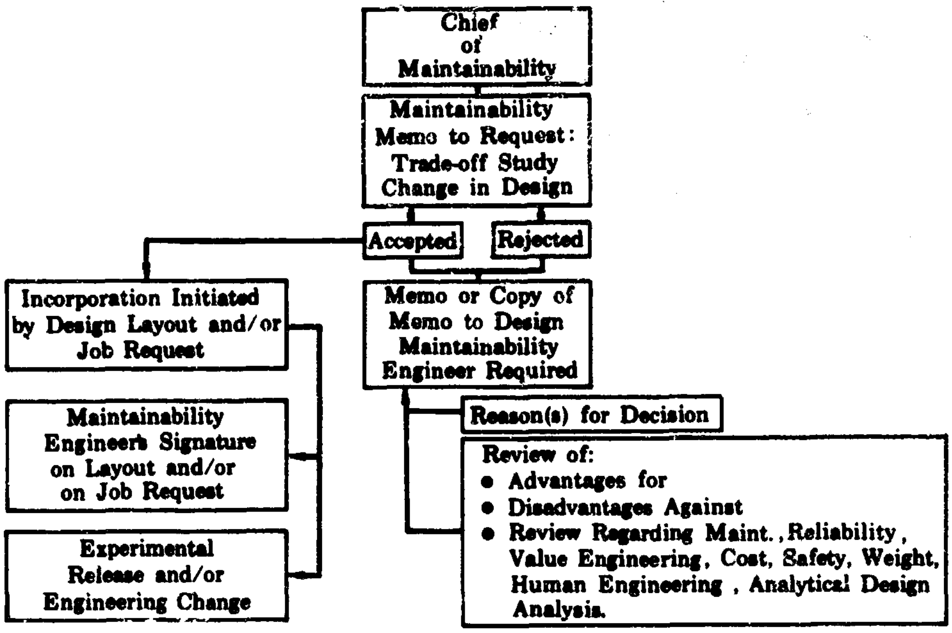


Figure 5. Documentation of Maintainability Requests Flow Chart — FD 17560 FI

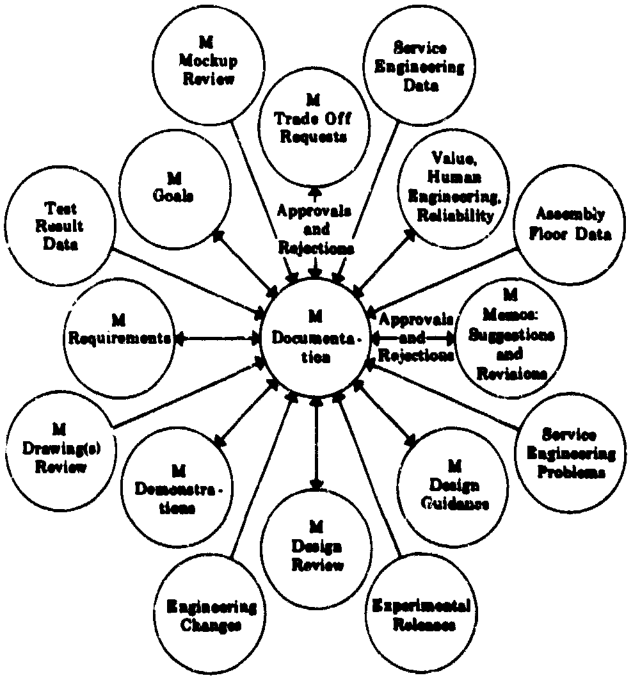


Figure 6. Integration of Documented Data — FD 17657 FI

J. MAINTAINABILITY PLAN MILESTONES

- Prototype Engine Design Review
- P&WA Design Reviews
- Major Program Reviews
- Formal Mockup Review

The Major Program Reviews as well as the formal Mockup review will be coordinated and conducted with FAA/Airline and airframe contractor personnel in attendance. The dates of these reviews and additional detailed information is presented in the Configuration Management Plan, Volume V, Report C.

The following additional Maintainability Milestones will be accomplished during Phase III:

1. Establishment of Airborne Integrated Data System Parameters
2. Follow-up Maintainability Assurance Review with FAA/Airlines and Airframe Contractor
3. Demonstration of Engine Maintainability
4. Review Engine Maintenance Tooling and Allied GSE
5. Engine Maintenance Manual Review
6. Establish Maintainability Index Goal.

K. PHASE II-C MAINTAINABILITY SUMMARY

The JTF17 engine has been designed to meet the maintainability objectives and requirements of the Supersonic Transport Program. The objectives outlined in the Pratt & Whitney Aircraft Phase II-C Maintainability Plan FR 1465B were used to establish the initial maintainability goals. Attainment of these goals has been accomplished during Phase II-C.

The goals established during the Phase II-C program were specifically tailored toward the incorporation of features which provide an extensive improvement over present maintenance concepts.

These improved maintenance features have contributed significantly in accelerating the present test program. The improved inspection methods have provided a significant improvement in the capability to inspect internal engine parts on the test stand with the JTF17 test engines as compared to previous engine models. The successful application of borescope and radioisotope methods of inspection to the engine has demonstrated the ability of the engine to conform to the "inspect, test and correct as necessary" concept of the TERP program. The unitized engine construction (modular concept) makes possible a minimum time delay in performing scheduled teardown inspections. Preliminary engine parameters have been established for monitoring engine condition through the Airborne Integrated Data System (AIDS).

The reader is referred to Exhibit B for a listing of the maintainability features that have been incorporated in the JTF17 engine during the Phase II-C program. The features listed in the Exhibit reflect the results of a comprehensive analysis of inputs and data compiled from the following sources.

1. FAA/Airline and airframe contractors comments during their periodic reviews of the engine design

2. Individual airline comments.

3. Analysis of Field Service Data on present commercial engines which highlighted recurring problem areas.

4. Mockups as follows:

   a. Full size external mockup of the Boeing and Lockheed engine configuration to establish required interfaces and accessibility of maintenanc features.

   b. One-tenth size mockup to demonstrate unitized construction assembly-disassembly techniques.

   c. One-half size mockup of engine cross section to demonstrate and verify the straight line removal of major engine assemblies.

   d. Full size mockups of the compressor, burner and

5. Full size mockup of the gas generator igniter area to demonstrate accessibility of igniters through the duct heater diffuser case struts.

Improvements and refinements established during Phase II-C, the FAA/Airlines reviews, and the mockup studies will be reflected in the Phase III program as additional objectives are required to support and develop the highest attainable engine maintainability in the operational phase.

For every build, sonic analysis microphones have been placed in close proximity to engine to obtain acoustic signatures of the engine. Reduction of these data has shown excellent signal-to-noise ratios and has permitted identification of discreet component frequencies. Extensive testing will be required to relate amplitudes and frequencies to engine conditions.

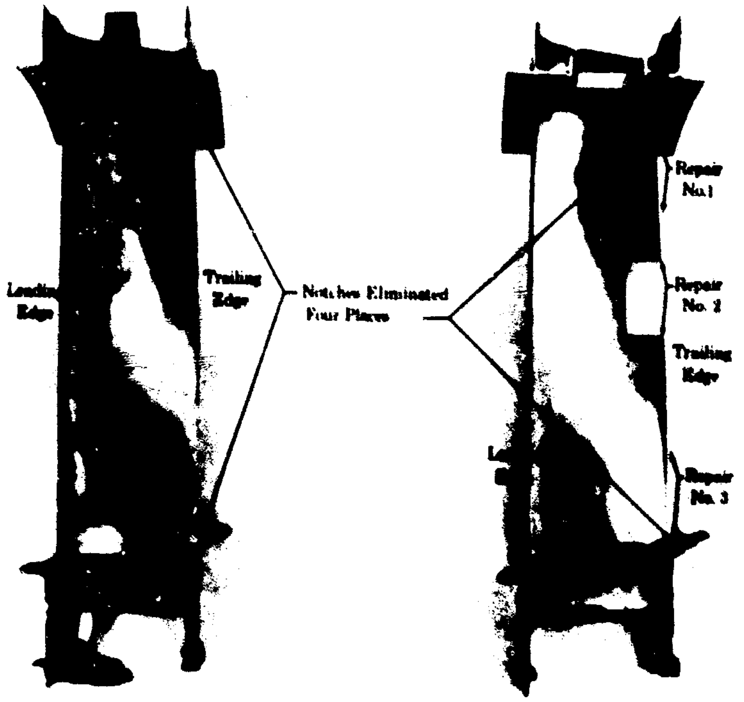
P&WA has been monitoring similar sonic analysis programs currently undergoing evaluation at two major airlines.

Repairability of all parts in the JTF17 engine has been and will continue to be an important consideration in the selection of materials. Some of the materials being used in the JTF17 that have not been used in

present commercial engines and for which repair procedures have been developed are as follows:

Material	Part
A-110 Titanium	Fan and Intermediate Cases
Inco 718	Compressor Vane and Cases Burner Cases
Waspaloy	Turbine Case and Exhaust Case
811 Titanium	Compressor Vanes and Reverser-Suppressor

The front mount case and the intermediate case for the JTF17 engine are to be manufactured of A-110 titanium. Overhaul shop level weld repairs for this material have been demonstrated on J58 inlet guide vanes as well as 1st-stage stator assembly. A full-length trailing edge section of a vane to a depth of ½ in. was removed and replaced by welding in a new section, as shown in figure 7.



Vane No 1 Entire trailing edge of this vane was removed and replaced with a solid titanium insert

Vane No 2 This vane contained three ½ in. long trailing edge repairs. One repair section was removed for more thorough examination

Figure 7. Weld Repair Demonstration on J58 Inlet Guide Vane FD 17743 FI

Inco 718 material, which is used in the JTF17 5th, 6th, and 7th vane and cases and in the diffuser and burner cases, is readily weldable and does not require any solution heat-treat cycle after weld repair, since it is not susceptible to cracking when operated at aging temperature.

Considerable progress has been made in the past several years in the weld repair at overahul shop level of Waspaloy. A typical weld repair of a cracked strut wall in a J58 Waspaloy Diffuser Case is shown in figure 8. This example is used to illustrate the fact that weld repairs have been successfully performed on large complicated cases. Similar repairs will be made available for J58 turbine cases when and if required.

Figure 8. Typical Weld Repair of Cracked Strut Wall in J58 Waspaloy Diffuser Case FE 48888 FI

For Waspaloy repairs, a solution heat-treat is required after welding if the part is to be run at aging temperatures, otherwise cracking will be experienced. By employing lightweight fixturing so that the part is not restrained during heat-treat, only negligible distortion is experienced. Another major consideration in this type of repair is to remove, when possible, all the weld-heat-affected zone and to fit a "dogbone" shaped patch to the parent material, as shown in figure 9.

Figure 9. "Dogbone" Patch FE 50377

FI

Since many of the large sheet metal cases in the reverser-suppressor will be constructed of 811 titanium, weld repair programs have been conducted demonstrating that only a negligible degradation of tensile properties is experienced ~~when the~~ stress relief cycle is omitted after a weld repair is made, thus facilitating field repairs.

L. TECHNICAL STANDARDS

1. Technical Specifications/Standards/Administrative Directives

    1. P&WA FTDM-208 Design Maintainability Check List

    2. MIL-M-26512C Maintainability Program Requirements for Aerospace Systems and Equipment

    3. Spectrometric Oil Analysis - Overhaul and Repair Department - Naval Air Station, Pensacola, Florida

    4. MIL-STD-803 Human Engineering Design Criteria for Aerospace Systems and Equipment

        Part 1 - Aerospace System Ground Equipment

5. WR-30 Integrated Maintenance Management for - Aeronautical Weapons - Weapon Systems - Related Equipment - Bureau of Naval Weapons, Department of the Navy, Washington 25, D.C.

6. ASD Technical Report 61-381 - Guide to Design of Mechanical Equipment for Maintainability - Behavior Sciences Laboratory, Aeronautical Systems Division, Air Force Systems Command, United States Air Force, Wright-Patterson Air Force Base, Ohio

7. FAA Advisory Circular 120-17

8. Lockheed-California Design Handbook - SST Maintainability Design Guidelines

9. Lockheed-California Equipment Document No. 422540 - Design Guide for Maintainability

10. Boeing Document No. D6-9458 Maintenance Design Guide, commercial SST.

EXHIBIT A TO SECTION I

AIRLINE MAINTENANCE PLAN

The following maintenance levels have been established based on the present commercial airline requirements and reflect the maintenance capabilities that have been designed into the JTF17 engine. Performance of the various maintenance tasks at the different maintenance levels varies with the individual commercial air carriers; however, the listed maintenance tasks can be accomplished by the airlines. The frequencies of inspection will be established to coincide with the inspection cycle of the aircraft.

A. TRANSIT INSPECTION - ENGINE INSTALLED - COWL CLOSED

1. Visual check of engine inlet and fan section for indications of foreign object damage and other abnormal damage.

2. Visual check of the engine exhaust area, condition of the reverser-suppressor, duct heater, and turbine exhaust area of the basic gas generator.

3. Visual check of the engine accessory section through airframe supplied access parts, for fuel, oil and hydraulic leaks, accessory linkage, and general condition of plumbing and accessory hardware.

4. Borescope inspections, if required, can be performed through airframe supplied access panels to view the following:

   a. Primary burner
   b. Primary fuel nozzles
   c. Leading edges of nozzle guide vanes
   d. Leading and trailing edges of all stages of high compressor
   e. Leading edges of 1st- and 2nd-stage turbine blades.

B. TERMINAL INSPECTION - ENGINE INSTALLED - COWL CLOSED

Terminal inspection requirements include the transit inspection requirements. Terminal inspection also requires an oil level check and an ignition check. The continuity of the ignition system is checked by performing an aural check of the ignition plugs without removal of the plugs or disassembly of the engine cases. The igniter plugs can be readily removed for inspection or replacement.

C. PHASED INSPECTION - ENGINE INSTALLED - COWL OPENED

Phased inspection requirements include the terminal inspection requirements. In addition, the following items can readily be inspected for general conditions, evidence of chafing, rubbing, disengagement, leakage, distortion, discoloration due to abnormal temperature exposure, burnthroughs, fatigue cracks, etc.

1. Inspection of all accessories and controls.

2. Inspection and replacement of fuel and oil system filters and screens, including all last chance screens.

3. Inspection of magnetic chip detector plugs.

4. Visual check of fuel, oil and hydraulic lines for leakage, and rubbed areas due to loosening of loop clamps.

5. Visual check of all accessory linkage and pulley cables for disengagement or loss of tension.

6. Visual check of all actuators for leakage and shaft wear.

7. Check of engine flange joints for leakage or distortion which would indicate internal discrepancies.

8. After removal of the fan duct diffuser case access ports:

   a. Check main fuel manifolds for leakage and general conditions.

   b. Check condition of the start bleed valves.

   c. Check high compressor case flange joints for leakage or distortion.

9. Check harnessing for fraying of shielded jacketing.

10. Visual inspection of fan blade conditions for foreign object damage or other abnormal wear.

11. Borescope inspection of the high compressor rotors, main burner area and turbine rotors can be accomplished if required.

12. Visual inspection of the duct heater can be performed through the exhaust end of the engine and by use of borescope through the igniter holes.

13. Visual inspection of the duct heater fuel nozzles from exhaust end of engine.

14. Visual inspection of the 3rd-stage turbine blades for wear with the aid of borescope equipment from exhaust end of engine.

15. Inspection of thermocouple and harness for proper response and continuity.

16. Aural check of igniters.

17. Visual inspection of turbine exhaust vanes.

18. Inspection of clamshell reverser doors for distortion and proper positioning.

19. Visual inspection of the reverser-suppressor trailing edge flaps.

20. Check of the blow-in-door flap condition.

21. Check of the duct heater Zone II turbulators.

22. Check of the duct heater Zone II fuel injectors.

23. Visual check of duct heater liners.

24. Visual check of duct heater nozzle flaps and seals.

25. Check of duct heater nozzle flap bearings.

26. Check of heatshielding on No. 4 bearing compartment oil supply and scavenge line.

27. Check of reverser door linkage and bearings.

D. LIGHT MAINTENANCE - ENGINE INSTALLED - COWL OPENED

1. Inspection of chip detectors, if required.

2. Inspection and replacement of filters and screens which include all last chance screens (on outside of engine).

3. Borescope inspection of items listed in A.4.

4. Radioisotope inspection from inlet and exhaust area of engine through low turbine. To gain access to the engine inlet requires provisions on the airframe inlet. To gain access from the exhaust end would require removal of the inner exhaust nozzle cone, the No. 4 bearing compartment oil supply and scavenge tubes, the No. 4 bearing compartment dump air collector, the No. 4 bearing compartment cover, the scavenge pump pinion gear and the No. 4 bearing compartment-low turbine shaft inner cover.

5. Inspection and replacement of all igniters and exciters. The igniters for the primary burner are readily available from the outside of engine, as they are mounted on the outer surface of the duct heater and extend through struts into the gas generator area where they are mounted to the main burner case into the main burner. The strut openings are adequate to permit standard tooling to be used to remove the main burner igniters.

6. Replacement of all controls. The controls and accessories are mounted to permit quick disassembly with a minimum amount of plumbing and other attachments to disconnect. The controls are positioned to permit removal of any one unit without disturbing any adjacent unit. The human engineering factor has also been considered, as ample space between controls has been provided for safe handling, and handling provisions have been incorporated for mechanical lifting on all units in excess of 44 pounds.

7. Replacement of duct heater fuel nozzles. The duct heater fuel nozzles are readily accessible for removal and replacement. They are located on the outer surface of the duct heater and are designed to preclude reverse installation. Replacement of the fuel nozzles can be accomplished after removal of the fuel manifolds.

8. Replacement of the main burner fuel nozzles. The main burner fuel nozzles are located on the diffuser case and are accessible for removal through the access covers located on the fan duct diffuser case. The fuel nozzles can be replaced after removal of the fuel manifolds, and are designed to preclude reverse installation. The outer section of the fuel nozzle support houses a replaceable fuel strainer.

9. Replacement of start bleed valves. The start bleed valves are located on the high compressor case of the gas generator and are accessible through the access covers located on the fan duct diffuser case. Valves may be individually removed and are designed to preclude improper installation.

10. Replacement of main fuel manifolds. The main fuel manifolds are mounted to the main burner fuel nozzles on the gas generator and are readily available through the access covers located on the fan duct diffuser case.

11. Replacement of Turbine Discharge Pressure (P_{t7}) and Turbine Discharge Temperature (T_{t7}) probes, harness and junction boxes. The P_{t7} and T_{t7} probes are readily visible from the exhaust end of the engine and are located behind the turbine exhaust case vanes for maximum accessibility. Inspection, heat check, and replacement of these probes can be accomplished through the exhaust end without requirement of any engine disassembly. In order to inspect and replace the harness and junction boxes for the T_{t7} probes, it is only necessary to remove the duct heater inner nozzle cone.

12. The No. 1, No. 2, and No. 3 bearing compartment scavenge pumps are located on the outside of the engine and are readily available for inspection and replacement.

13. The Secondary Accessory Gearbox is readily available for inspection and replacement. The scavenge pumps, oil pressure pump, and oil filter are individual component assemblies that fit into cavities within the gearbox housing. These are readily removable for inspection, cleaning, or replacement without further engine disassembly.

14. The main and secondary gearboxes are drained by a gear-type scavenge pump at the bottom of each gearbox housing. The scavenge pump is accessible for inspection or replacement without removal of the gearbox or accessories.

E. HEAVY MAINTENANCE - ENGINE INSTALLED - COWL OPENED

1. Combustion Chamber Area Inspection and Maintenance

Past experience indicates that the burner, transition ducts, and 1st-stage turbine nozzles are primary hot section problem areas. Access to these parts requires removal of the reverser-suppressor, the duct heater nozzle, and the primary burner case. The primary burner case is segmented and can be removed without disassembling the turbine section. The transition ducts are also segmented to facilitate removal. The 1st-stage turbine nozzle vanes are then exposed for inspection and replacement if required. The vanes are individually replaceable. Repair capabilities have been maximized in this area from the standpoint of accessibility. Borescope inspection of the burner area from the outside of engine can be used to determine the requirement for performing a Combustion Chamber Area inspection (CAI). With the eight borescope ports provided for the inspection of the main burner area, adequate inspection can be made to determine the necessity of performing the CAI. The extension or elimination of the CAI may be possible due to the adequate and more frequent borescope inspections made during the Visual Check - Cowl Closed and the Light Maintenance - Cowl Opened inspection and maintenance periods.

2. Unitized Construction - Modular Removal for Replacement

With the modular concept of major engine assemblies, compressor and turbine rotor units can be replaced as assemblies with no further dis-assembly-reassembly and rebalancing required. The following are features designed into the engine which have this capability with the engine installed.

1. The elimination of the inlet case and the accompanying inlet guide vanes in the JTF17 engine design makes the fan assembly readily accessible for removal without disturbing the No. 1 bearing compartment, turbine or the front mount case. Fan blades are moment-weight classified, thus permitting individual replacement.

2. Individual replacement of the 1st- nd 2nd-Stage Fan Rotor and Stator Assembly.

3. Replacement of the No. 1 bearing and seal assembly.

4. Replacement of the No. 2 bearing and seal assembly.

5. Replacement of the turbine exhaust cone from the exhaust end of the engine, without disturbing the reverser-suppressor.

6. Replacement of the No. 4 bearing and seal assembly.

7. Replacement of the No. 4 bearing scavenge pump and pinion drive gear without disturbing the turbine assembly.

8. Replacement of the reverser-suppressor as an assembly.

9. Replacement of the duct heater nozzle assembly aft of the rear engine mount ring as part of the reverser-suppressor assembly or separately after the reverser-suppressor is removed. Removal of the duct heater nozzle permits replacement of the outer duct heater liners, replacement of Zone II turbulators, replacement of Zone II fuel injectors and nozzles and the replacement of duct heater combustors.

10. Replacement of the low turbine after removal of the reverser-suppressor, and the duct heater nozzle aft of the rear mount ring.

11. After removal of the low turbine assembly, the high turbine disk and blade assembly can be removed for repair or replacement. The high turbine disk and blade assembly contains moment weight classified blades to permit individual replacement.

EXHIBIT B TO SECTION I
MAINTAINABILITY FEATURES
OF THE
PRATT & WHITNEY AIRCRAFT JTF17 SUPERSONIC TRANSPORT ENGINE

The following list summarizes the maintainability features which have been incorporated into the prototype and production engine design. These features reflect the high maintenance accessibility/low maintenance cost concept of the JTF17 engine design.

Highlighting these features are certain significant maintenance features which have provided a major improvement over present maintenance concepts.

1. Improved inspection techniques utilizing borescope and radiosotope methods to ensure early detection of incipient failures and provide a tool toward the successful application of the TERP program.

2. Unitized engine component construction (modular concept) of major engine assemblies which permits replacement of major engine sections with a minimum of teardown.

   Rotors are balanced within their cases with the stator vanes in place. The resulting balanced compressor or turbine unit is then assembled into the remainder of the engine. Current powerplants require assembly of the rotor alone, balancing, disassembly and then a subsequent stage-by-stage buildup in the engine. In addition to the reduction in maintenance time, the improved balancing procedure reduces the possibility of rotor shift or assembly error after balancing.

3. Overhanging the fan beyond the front bearing and eliminating the conventional inlet guide vane structure and the inherent anti-icing problems associated with the inlet structure.

4. The engine has been designed to provide for maximum installed repair and replacement capabilities. Fan Assembly, Turbine Exhaust Assembly, Reverser-Suppressor, Low Turbine Assembly, No. 1, No. 2 and No. 4 Bearings and their Seal Assemblies, are all designed to permit replacement with the engine installed. The design of individual components and materials used reflect maximum repair capabilities.

A. INSPECTION PROVISIONS (See Figures 1 and 2)

The primary features incorporated into the design allow detection or evaluation of damaged parts--without engine disassembly--such as filters, screens, and magnetic plugs, and also allow access for borescope and radioisotope inspection. All of these features are accessible to maintenance personnel with the engine installed in the aircraft, and are located as follows:

1. Filters

   a. Main fuel pump inlet

   b. Fuel control inlet

   c. Hydraulic pump discharge

   d. Oil tank

2. Screens

   a. Located in the fuel pump interstage bypass

3. Magnetic Chip Detectors

   Provisions have been made for installation by the airline companies, if they desire, of magnetic chip detector plugs in the following locations:

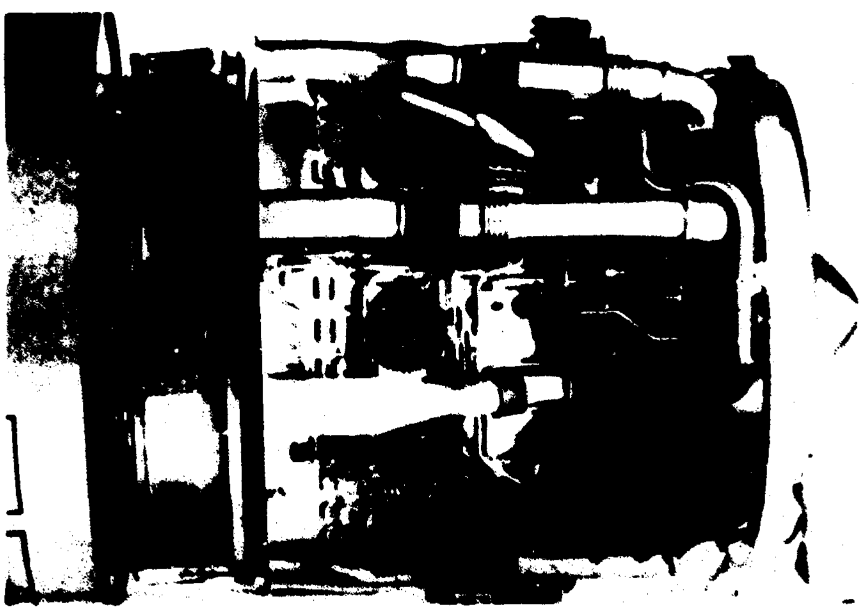
   a. Main oil filter

   b. No. 1 and No. 2 bearing compartment sump

   c. Main gearbox

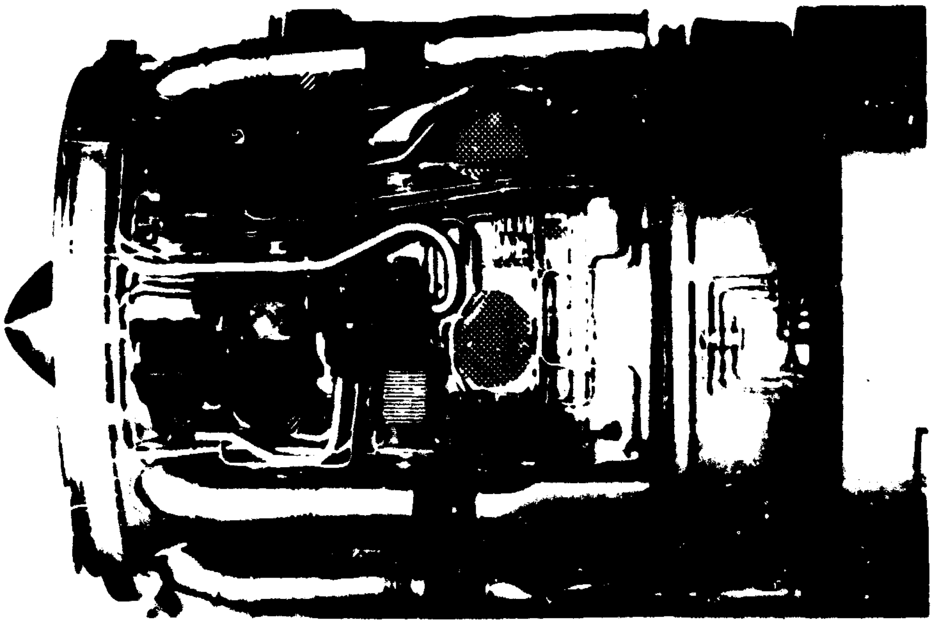
   d. Oil pump gearbox

   e. Oil tank



Filters
Borescopes and Inspection Ports
Magnetic Chip Detector

Figure 1. JTF17 Service Check and Inspection Points - Right Side — FD 17562 FI



Filters
Borescopes and Inspection Ports
Magnetic Chip Detector

Figure 2. JTF17 Service Check and Inspection Points - Left Side — FD 17563 FI

4. Borescope Inspection (See figure 3.)

   a. Access is provided at each stator stage of the high compressor bottom centerline providing for inspection of the leading and trailing edges of all high compressor blades. Provision for manual rotation of the high compressor to facilitate borescope inspection has been incorporated into the main gearbox.

   b. Each igniter hole of the primary burner, plus six additional holes are provided for inspection of the burner, fuel nozzles, and leading edges of 1st-stage turbine vanes.

   c. Access is provided in front of 1st- and 2nd-stage turbine blades at the bottom centerline for inspection of the leading edges of these blades.

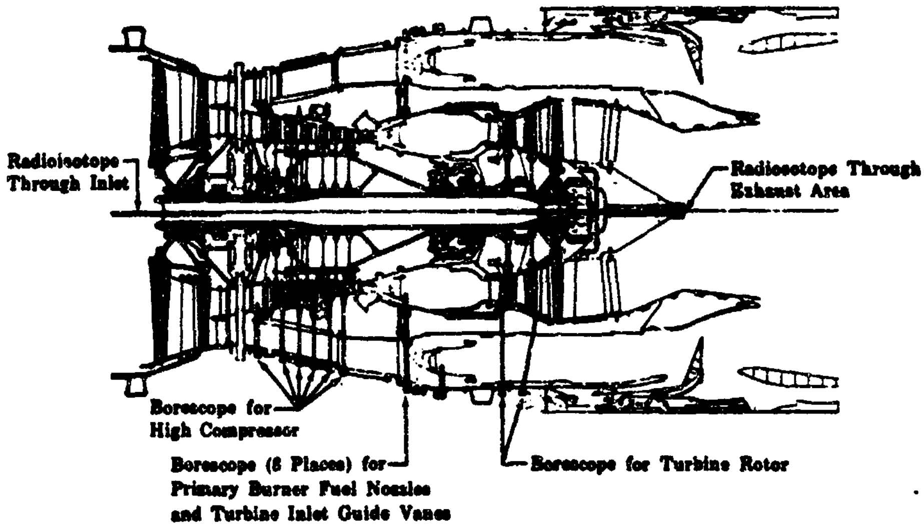


Figure 3. JTF17 Inspection Features FD 17561 FI

5. No special provisions are required to inspect the blades and vanes of the fan stages or last turbine stage. These components are accessible through the engine inlet and exhaust. Closer inspection of the 1st-stage fan blades can be accomplished with the borescope by removing a compressor inlet temperature (T_{t2}) sensor on the front mount case and using the sensor hole as access to fan blades.

6. Radioisotope Inspection (See figure 3.)

   The low rotor shaft provides access for radiographic equipment. This feature allows the inspection of any suspected problem area in the internal components of the engine.

   Radioisotope inspection of the engine is a primary factor, along with borescope and inflight recording systems, in the elimination of the fixed TBO system of overhaul.

B. REPAIR AND REPLACEMENT OF CONTROLS AND ACCESSORIES

The controls and accessories have been designed and located for maximum accessibility and require minimum disassembly of adjacent hardware to repair or replace any specific unit.

1. Igniters and exciters on the duct heater are located below the engine horizontal centerline and are readily accessible.

2. Igniters on the gas generator are also located below the engine horizontal centerline and are accessible from the outside of the engine. These igniters extend through struts in the duct heater diffuser case to the main

burner in the gas generator. The igniters can be removed using standard socket wrenches and extensions.

3. All controls are located on the engine permitting the greatest accessibility that can be provided. Any one individual control can be removed without the need of disassembly of any adjacent control Where applicable, the controls contain quick-disconnect features to reduce maintenance time. Handling points have been provided on all controls that exceed 44 pounds to permit removal by additional personnel or a mechanical device.

4. Duct heater Zone I fuel nozzles are located radially around the outside of the engine and can be readily replaced after removal of the fuel manifold. Individual fuel nozzles can be replaced as required without the need of further disassembly in the duct heater area.

5. Main burner fuel nozzles are located radially around the gas generator and can be readily replaced after removal of the access ports provided. Access ports are strategically located to provide greatest access to accessories and components on the gas generator.

6. Start bleed valves located on the high compressor case of the gas generator are also readily accessible for replacement through the access ports provided on the fan duct diffuser case. Alignment pins and offset holes are used to locate the start bleed valves to orientate the tubing connection properly.

7. The duct heater fuel manifolds are accessible from the outside of the engine and require no prior disassembly of adjacent parts for replacement.

8. Replacement of the main burner fuel manifolds can be accomplished through the access ports provided.

9. Scavenge pumps, oil pressure pump, and oil filter are individual component assemblies that fit into cavities within the gearbox. They are readily removable for inspection, cleaning, or replacement without further engine disassembly.

10. All tapped holes in the control housings are provided with replaceable steel inserts, and all brackets, attachments, or other areas subject to wear are separable from the housing or are provided with replaceable bushings.

11. The main and secondary gearboxes are scavenged by a gear-type scavenge pump at the bottom of each gearbox housing. The scavenge pump is accessible for inspection or replacement without removal of the gearbox or accessories.

12. All hydraulically operated actuators are readily accessible from the outside of engine, requiring only the disconnecting of the attaching hydraulic lines. Simple mounting allows quick and easy actuator replacement.

13. Replaceable bearing bushings are incorporated into the oil pump to facilitate low cost replacement of worn units.

14. Engine component and accessory drive shaft carbon seals are replaceable without gearbox disassembly.

15. Simple link mounting for accessory gearboxes have been incorporated to provide easy replacement of units.

16. No. 4 bearing scavenge oil pump mount has been foolproofed to prevent improper assembly.

17. Provisions on oil tank have been incorporated for both remote and gravity fill, and quantity indication.

18. A valve is located at the bottom of the oil tank to facilitate draining and flushing.

C. REPAIR AND REPLACEMENT IN FAN AREA

1. Special provisions have been made to permit removal of individual 1st-stage blades, the 1st-stage rotor assembly, or 1st- and 2nd-stage blades (including the 1st-stage stator) horizontally without disturbing the bearings.

2. The fan assembly has been foolproofed to prevent incorrect or reverse assembly.

3. Moment weight classified blades are provided in the 1st and 2nd stages of the fan to permit individual blade replacement without rebalancing.

4. Different correction weight types are used for the dynamic rotor balance than are used for disk and blade assembly balance. This provides easy identification and ensures that the individual stage balance will not be lost if the rotor is torn down and reassembled.

5. Provisions have been made for attaching fixture(s) for radial and axial support between the static and rotating parts of the Fan Rotor and Stator assembly when replacing as a unit.

6. The Fan Rotor and Stator assembly as a balanced unit may be replaced without removal of the front mount case, and without disturbing the turbine drive section.

7. Provisions to release the tight fit between the 1st-stage Fan Rotor and Disk assembly without disturbing the 2nd stage have been incorporated.

8. Anti-rotational retention slots have been incorporated into the low turbine shaft to permit removal of the fan-turbine coupling nut.

D. INTERMEDIATE CASE

1. Bolted configuration of splitter nose piece permits easy replacement of the fan exit vanes and the fan duct diffuser vanes.

2. Provisions have been designed into the intermediate case for supporting engine when the front mount case is removed.

3. Dowel pins and offset holes are used to align the intermediate case rear flange and the aerodynamic brake vane flange to ensure proper mating of the synchronizing linkage.

E. HIGH COMPRESSOR

1. The high compressor is designed to prevent reverse installation of any disks by the use of different pilot diameters.

2. The high compressor assembly, consisting of both the rotor and stator and cases, is assembled and balanced as a unit eliminating major disassembly and complex stage-by-stage buildup required on other engines. This also eliminates assembly errors and imbalance induced during the rebuild into the engine.

3. Jackscrew holes have been added, where required, to flanges where a press fit occurs to facilitate disassembly.

4. Piloting diameters have been incorporated to engage prior to engagement of knife-edge-type labyrinth seals to prevent damage to seals during assembly or disassembly.

5. Replacement of riveted-on knife-edge seals and lands can be accomplished readily and provides a low cost replacement configuration.

6. The high compressor front hub is keyed to the towershaft drive gear to permit proper reassembly, thereby maintaining the balanced limits on the high compressor assembly.

F. PRIMARY COMBUSTOR AND DIFFUSER

1. The concept of supporting the combustor and transition duct from the inner and outer burner case walls ensures efficiency for the design and provides for removal of the entire annular combustor or replacement of individual burner segments without removing the turbine. The outer burner case is split into two 180-degree segments to

permit access to the segmented burner sections, the transition ducts, the 1st-stage turbine vanes, and the 1st-stage turbine outer air seals at the inspection periods.

2. Design of the primary burner has been revised to permit removal without disturbing the 24 fuel nozzles. This precludes the necessity of fuel nozzle removal and creating potential leak points at fuel manifold connections due to disassembly.

3. The fuel nozzles metering section has been designed to permit usage on both the primary combustor system and the Zone I system of the duct heater.

4. Fuel manifolds for both the primary and Zone I combustors consist of individual nozzle supply pads and tubing welded together to form an assembly, supplying groups of 5, 6 and 7 nozzles thus reducing assembly time.

5. Each fuel nozzle is protected from fuel contamination by a strainer located in the nozzle cap. Each strainer is retained by its own cover, and the removal of a spanner nut allows inspection and cleaning or replacement without disassembly of the primary fuel manifold plumbing.

6. The duct heater Zone I fuel nozzles and the combustion chamber fuel nozzles are designed to prevent reverse installation.

G. TURBINE AND TURBINE EXHAUST

1. The low turbine assembly, consisting of both the rotor and stator and cases, is assembled and balanced as a unit, eliminating major disassembly and complex stage-by-stage buildup. This eliminates assembly errors and imbalances induced into the engine during rebuild.

2. Ability to readily remove the low turbine shaft front cover to facilitate access for radiographic inspection has been provided.

3. The turbine exhaust temperature and pressure probes are mounted aft of the turbine exit vanes for ease of accessibility. The probes can be removed from the exhaust end of engine without any prior disassembly of the reverser-suppressor or turbine exhaust assembly.

4. The Turbine Exhaust Gas Temperature harness and junction boxes are readily accessible after removal of the duct heater inner liner cone. The use of junction boxes eliminates the need for cannon connectors, thereby improving the electrical harness connection points.

5. Provisions to support the low turbine fan drive shaft with the No. 1 bearing and seal assembly unit removed has been provided in the ground support equipment list.

6. The high and low turbine assemblies are fool-proofed to prevent reverse installation of any disk by the use of different pilot diameters.

7. Jackscrew holes have been added, where required, to flanges where a press snap fit occurs to facilitate disassembly.

8. Piloting diameters on major components incorporating knife-edge-type labyrinth seals are designed to ensure that the unit is completely piloted prior to assembly or disassembly to prevent damage to seals.

9. Knife-edge seal rings and seal lands are riveted in units that are easily replaceable as a low cost item.

10. The turbine exhaust case can be replaced as a unit, after removal of the turbine exhaust nozzle. This permits ready access to the low turbine unit.

11. The high and low turbine assemblies contain moment weight classified blades which permit individual blade replacement without balancing.

12. Provisions for attaching fixture(s) for radial and axial support between the static and rotating parts of the rotor and stator assemblies when replacing the low turbine unit.

13. Offset holes are used on the turbine exhaust probe bosses to prevent improper installation of the T_{t7} and P_{t7} probes.

14. Provisions have been incorporated into 1st-stage turbine blades to permit measurement of blade stretch at inspection.

H. **REVERSER-SUPPRESSOR**

1. The reverser-suppressor can be readily removed as a unit. The complete unit can be removed or installed on the engine by removing or installing 20 bolts. Further disassembly, other than disconnection of the hydraulic lines and power lever interlock, is not required. The pattern of the bolt hole flange is designed to preclude improper orientation of assembly of reverser-suppressor onto the duct heater. This feature ensures alignment of hydraulic lines and power lever interlock.

2. Ground handling provisions have been provided on the reverser-suppressor to permit removal or installation.

3. Access panels have been provided on each side of the reverser-suppressor for ready access to the clamshell adjustment linkage and bearings.

4. During reverse mode operation the blocked and redirected exhaust stream is prevented from backflowing within the engine compartment by the use of free-floating flapper doors. Each door operates independently of the others and can easily be removed without disturbing the mounting or alignment of the other doors.

5. The clamshell is fabricated from nickel base alloy, which is easily weldable and which requires no subsequent heat treatment for strength.

6. The clamshell hubs and bearings are easily removed or inspected by removing the inside cover plate and outside access panel. The clamshell can be removed or left in place as desired. All hubs and bearings are interchangeable, thus eliminating matched sets or shims.

7. Hinges for the exit flaps and longitudinal seals are provided with replaceable bushings of wear-resistant alloy. The outer hinge seal is removable for inspection of the exit flap hinges. The limit stops for both inward and outward movement of the exit flap are easily removable.

8. Easy access is provided to the clamshell actuators by removing the outer access panels.

9. The throttle-reverser-interlock assembly is self-contained, shielded from dirt and foreign matter, and easy to service or replace.

I. DUCT HEATER

1. Partial duct heater assembly can be removed aft of the rear engine mount ring to facilitate inspection or replacement of the following duct heater burner elements.

   a. Outer duct heater liners
   b. Zone II turbulators
   c. Zone II inner and outer fuel injectors and manifolds
   d. Duct heater combustors
   e. Inspection of the outer and inner transition liners, segmented air scoops, and the 1st-stage turbine nozzle guide vanes.

2. The duct heater fuel nozzles and fuel manifolding is readily accessible for replacement as outlined in Section B.

3. Offset holes are incorporated into the duct heater case flange to permit orientated positioning at assembly.

4. Duct heater burner is retained by 8 burner retaining pins which are located on outside of engine and are readily accessible for replacement of quick disengagement of burner. Pins contain adequate puller facilities to overcome any binding due to distortion of duct heater burner.

J. BEARINGS AND BEARING COMPARTMENT SEALS

1. The No. 1 bearing and seal assembly can be removed and replaced without disturbing the turbine assembly. This can be accomplished with proper support of the forward end of the low turbine shaft.

2. The No. 2 bearing and seals can be readily removed from the inlet end of the engine, after removal of the No. 1 bearing. This design precludes the previous requirement of removing the intermediate case and substantially reduces the manhours required to perform this task.

3. The No. 4 bearing is readily accessible for replacement from the exhaust end of the engine and can be accomplished without any disassembly of major components of the engine.

4. Provisions have been incorporated to provide fixture(s) to support the low turbine assembly by shimming between the 3rd-stage turbine blade tips and the turbine exhaust case which will permit replacement of the following parts in the No. 4 bearing compartment:

   a. Ability to replace the No. 4 bearing inner race with rollers, after removal of the scavenge pump and scavenge pump drive gear.

   b. Ability to replace the No. 4 bearing outer race, after removal of the scavenge pump.

   c. Ability to replace the No. 4 bearing support.

   d. Ability to replace the No. 4 bearing carbon seals, after removal of the bearing support and the inner race with rollers.

   e. The ability to replace the No. 4 bearing oil scavenge pump.

   f. Ability to remove and replace the No. 4 bearing scavenge pump drive gear after removal of the scavenge pump.

5. Offset holes have been incorporated into the No. 4 bearing compartment cover to facilitate alignment with the oil scavenge pump, oil discharge tube and oil supply tube.

6. The No. 3 bearing is readily accessible after removal of the turbine exhaust case and low turbine assembly as a unit and the high turbine assembly.

7. The No. 3 bearing seal pressure air supply tubes have mount flange designed to prevent improper installation.

8. Puller grooves have been incorporated into the main bearing inner races to permit ease of disassembly, and to preclude the possibility of loading across a bearing during disassembly.

9. To eliminate bearing outer race spinning which has been a problem on current engines; the engine bearing races now incorporate anti-rotational features.

10. Bearing liners are of bolted-in configuration to preclude liner rotation.

11. Bearing compartment labyrinth seals include puller provisions for ease of disassembly.

12. Bearing inner races are axially restrained on shafts to prevent creeping and loss of end clearance.

TUBING

1. The unitized component construction concept of the JTF17 engine reduces the amount of external engine tubing, and thus reduces the various potential assembly problems that exist with the connection of tubing from inlet to exhaust section of engine.

2. Tubing is designed to detach at engine flanges to reduce maintenance complexity.

3. Tubing connections are staggered to preclude cross-connecting of lines.

4. Oil lines are designed to prevent trapping of oil in lines creating oil hiding problems. The flow paths are also designed to prevent trapping of metal particles. The metal particles, if collected and discharged in a lump from a trapped location, can create inaccurate readings on the screens and magnetic chip detectors.

5. Provisions have been incorporated for a ΔP measurement across main oil pump filter element for monitoring.

6. Tubing has been designed to eliminate interference with and avoid covering fuel nozzles, igni ers, access panels, start bleed valves, and borescope chip detector provisions.

L. GENERAL

1. Offset holes are incorporated into all engine case flanges to provide proper orientation of major components.

2. Captive fasteners are employed on the various flanges in areas where the nut is not easily accessible.

3. Chafe chamfers on lockwire holes in all items have been made large enough to avoid chafing through the wire and to minimize the time required to "thread" through and secure, by making an effective "lead in".

4. Ground handling provisions have been incorporated on both the front and rear mount rings in an accessible location to permit removal of engine from airframe.

5. Provisions for gaining access to the gas generator without further engine disassembly is accomplished by removing the outer and inner panels located forward of the duct heater and aft of the fan diffuser duct.

6. Engine replacement can be accomplished with the use of standard tools.

7. The engine has been designed to permit either vertical or horizontal assembly and disassembly.

8. The number of parts, bolted joints and sliding joints in any major assembly are minimized.

9. The engine design permits the extensive use of standard hand tools to reduce the number of special assembly tools required.

10. Adequate material has been provided around all tapped holes to permit repair to a larger thread size or incorporation of a replaceable insert.

11. The engine design has eliminated the use of cannon-type connectors except on the T_{t7} cable outlet and the N_1 tach indicator. Alignment pins have been provided on electrical connectors to provide proper alignment.

12. Parts having left-hand threads are clearly marked to indicate proper rotation for assembly or disassembly.

SECTION II
RELIABILITY PROGRAM

A. OBJECTIVE AND SUMMARY

1. Objective

The objective of the JTF17 Reliability Program Plan is to assure the highest possible engine reliability for the supersonic transport mission.

2. Summary

It is well understood that this is a formidable task and that it requires the closest possible coordination and best communication between Pratt & Whitney Aircraft, the Federal Aviation Agency, the airframe manufacturer and the airlines. For these reasons the plan emphasizes the use of management controls, and computerized information retrieval systems to obtain the most effective analysis and information distribution. Further, particular attention has been directed towards providing good program visibility for the organizations named above.

It is an essential part of the reliability program that the engine be installed and operated properly in service and further, that engine maintenance shall enhance rather than degrade reliability. Airline-airframe personnel will receive instruction from Pratt & Whitney Aircraft training programs in these areas. The feedback of service data to the project will provide corrective action for reliability improvement. These activities strongly influence reliability and are described in detail in the Maintainability, Safety, Human Engineering, and Product Support Plans.

Positive steps have been taken to provide a smooth interface between this program and the reliability programs at The Boeing Company and the Lockheed California Company; the definitions, reliability assessment methods, and mathematical models have been coordinated with both airframe companies.

With two exceptions, all of the data systems, analytical procedures and reliability documents and reports have been in use at the Florida Research and Development Center since the beginning of the J58 and RL10 Projects. Over 7000 rocket engine firings have been documented and classified for numerical reliability assessment. The two exceptions are the mathematical structure of the reliability model and the parameters selected for development reliability assessment. These new features have been developed specifically for the JTF17 Reliability Program to meet the requirements of the supersonic transport.

The organization of the Reliability Program Plan follows the assignment of reliability tasks:

1. Reliability Management
2. Reliability Interface
3. Reliability Goals & Features
4. Design Reliability Activities

5. Development Reliability Activities
6. Flight Test and Service Reliability Activities
7. Reliability Reporting and Milestones
8. Reliability Procedures Exhibits

Within each activity description, the Phase II-C progress is described in relation to the Phase III program.

B. RELIABILITY MANAGEMENT

1. Chief of Reliability

The Chief of Reliability reports directly to the Product Assurance Manager who in turn reports to the Program Manager.

The Product Assurance organization will provide positive management control of the related disciplines of reliability, maintainability, safety, quality assurance, human engineering, value engineering, standardization, and configuration control. It is an organization well suited to coordinating the airframe, engine, airlines and Federal Aviation Agency requirements in these areas. The assignment of a single individual responsible for each discipline will improve communications between Pratt & Whitney Aircraft and the organizations named above as well as centralize responsibility in a single individual directly under the control of JTF17 Program Management. The Product Assurance organization is described and illustrated in Section VI of this Report.

The Chief of Reliability directs and controls all of the tasks described within this program plan. The organization for the implementation of this plan is shown in figure 1. He is responsible for coordinating reliability functions with the airframe manufacturers, the Federal Aviation Agency, and the airlines. The Development and Design Reliability Groups receive their technical direction from the Chief of Reliability; Engineering Order Supplements that authorize reliability activity are originated by the Chief of Reliability. Administratively, the Design Reliability Group is located within the Design Department and the Development Reliability Group is located within Development Engineering Department. The Statistics Group provides staff consulting service to the Chief of Reliability and the Reliability Groups.

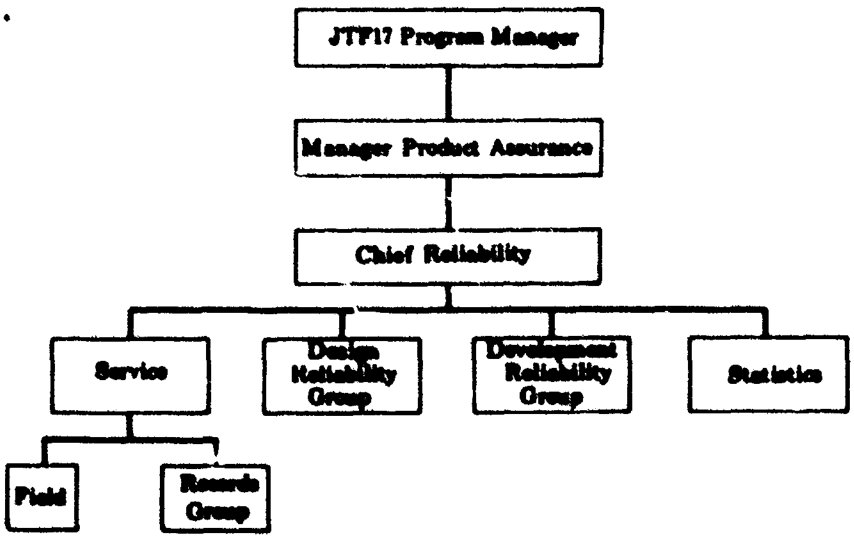


Figure 1. JTF17 Reliability Organization

FD 17545
FII

2. Design Reliability Group

The responsibilities of the Design Reliability Group are:

1. To ensure the maximum use of analytical reliability procedures within the JTF17 design.
2. To review the reliability aspects of all JTF17 design layouts, and indicate approval thereon.
3. To systematically relate reliability experience on other engine programs, development test and service data to the JTF17 engine design.

Paragraph E of this plan, Design Reliability Activities, is a detailed description of the tasks assigned to this group and is summarized below. Reporting procedures are outlined in Paragraph H, Reliability Reporting and Milestones.

Design Reliability Group Tasks

1. Review Service Data
2. Design Review
3. Redundancy Analysis
4. Trade Off Studies
5. Reliability Block Diagrams
6. Failure Mode and Effect Analysis (FMEA)
7. Apportionment
8. Mathematical Model

3. Development Reliability Group

The responsibilities of the Development Reliability Group are to:

1. Collect, process and analyze all JTF17 reliability test data.
2. Assess the reliability of the JTF17 engine based on test data in relation to the reliability goals and the reliability mathematical model established by the Design Reliability Group.
3. Provide reliability test requirements for the Integrated Test Plan.
4. Provide statistical analysis of reliability data to assist in component and engine development.
5. Operate a completely computerized Reliability Data Center.
6. Summarize the reliability status of the JTF17 project in periodic reports.

The specific tasks of the Development Reliability Group are detailed in Paragraph F of this plan, Development Reliability Activities and are summarized below. Reporting procedures are described in Paragraph H, Reliability Reporting and Milestones.

Development Reliability Group Tasks:

1. Reliability Data Collection
   a. Failure Data
   b. Critical Parts History
   c. Test Reports

2. Reliability Problem Files
3. Reliability Assessment
4. Statistical Reliability Analysis
5. Reliability Reporting

4. Statistics Group

Statisticians provide statistical service to the Reliability Groups. The Statistics Group is directed by the Chief Statistician who reports to the Chief of Reliability. The primary services provided by this group are:

1. Research in statistical reliability
2. Planning and designing experimental programs
3. Data accuracy and precision analysis
4. Statistical analysis
5. Education in statistical methods

5. Staffing the Reliability Function

The Development Reliability Group currently consists of 5 reliability engineers and coordinators working full time on JTF17 reliability. The Statistics Group has 3 statisticians on this project and the Design Reliability Group has o reliability engineers. The total Phase II-C staff of 15 people is expected to increase to 38 during Phase III.

6. Reliability Indoctrination and Training

The purpose of the indoctrination and training program is to provide an awareness of the objectives of the reliability program throughout the JTF17 organization.

The program consists of:

1. A film series
2. A seminar program
3. A consulting service
4. A formal education program

A series of three motion picture films is used to introduce new employees to reliability engineering methods. These films are:

1. Reliability Considerations in A Development Program
2. Increasing the Efficiency of Development Testing
3. Reliable Product Development at Pratt & Whitney Aircraft

The first two of these films illustrate the concepts employed in reliability and statistical analysis. The third film is a presentation of the design, development and manufacturing cycle employed by Pratt & Whitney Aircraft to achieve the maximum product reliability. These Pratt & Whitney Aircraft films are widely used in training programs and have been shown at the U.S. Naval Bureau of Weapons, the U.S. Naval Academy; Rolls Royce Limited, Grumman Aircraft Corporation, Cambridge

University, University of Wisconsin and the Royal Statistical Society. A seminar program of twelve lectures has been conducted over the years by Mr. Dorian Shainin, Vice President of Rath and Strong Incorporated, who is a consultant in reliability to Pratt & Whitney Aircraft. This program has been given repeatedly at Pratt & Whitney Aircraft in both Florida and Connecticut. The lecture notes have been published as a Pratt & Whitney Aircraft report and will be published next year as a formal textbook by Mr. Shainin.

A formal graduate education program is available to Pratt & Whitney Aircraft engineers through the University of Florida. A number of engineers have already obtained their Master's degree under this plan. Mr. L. W. Green of the Development Reliability Group and Mr. D. L. Colbert of the Statistics Group lecture in reliability and statistics in this program.

The Statistics Group is organized as a consulting service to engineering. Education in applied statistics is a byproduct of this service, and virtually all engineering groups now employ statistical analysis in their routine operations.

C. RELIABILITY INTERFACE

1. Airframe-Engine Interface

Pratt & Whitney Aircraft recognizes that it is necessary and in the best interest of the SST project to coordinate and exchange certain reliability analyses data and information with the airframe manufacturer.

A reliability interface agreement has been coordinated with the Lockheed California Company and several reliability coordination meetings have been held. Definitions and groundrules for reliability assessment have been outlined. Pratt & Whitney Aircraft has supplied reliability estimates to the Lockheed California Company for the L-2000-7 mathematical model.

A reliability interface agreement has also been coordinated with The Boeing Company. The Second Edition of the JTF17 Failure Mode and Effect Analysis was provided to both LCC and TBC.

Copies of the agreements are included with the airframe contractor's proposal to which the reader is referred for details.

2. Vendor Reliability Requirements

Pratt & Whitney Aircraft requires that suppliers of vendor-designed components recognize the concept of inherent reliability in design. Vendors of such equipment will conduct a reliability program similar to that described herein for the JTF17 engine. The procedures for component reliability control and quantitative reliability assessment are defined in detail by the purchase specification. A sample specification is shown in Volume III, Report B, Section III. Vendors and subcontractors must provide assurance that:

1. Adequate design margin exists
2. The product will meet mean time between failure and time between overhaul (if applicable) objectives consistent with

the objectives established for the engine.
3. The design is safe
4. Reliability is retained during manufacturing, test and design phases
5. Effort is directed toward elimination of human induced errors

Various support groups including the Purchasing Department, Quality Assurance, and Project Materials Control assist in assuring that potential suppliers are qualified technically, financially, and managerially to fulfill their commitments. The Purchasing Department maintains a list of qualified vendors who have established their capabilities through past performance records on Pratt & Whitney Aircraft engine programs. Qualifications are reassessed where new and unusual technical objectives are involved. Before an order is placed with a new vendor for a vendor-designed component, a survey is conducted by a team composed of Project Engineering, Purchasing, and Product Assurance personnel to determine the subcontractor's total capabilities.

The Program Manager's organization works closely with suppliers to assure that reliability and safety requirements are met and maintained. The cognizant Project Engineer, assisted by the Chief of Reliability and the Reliability Groups, has the responsibility for providing reliability and safety requirements for subcontracted items and assisting the Purchasing Department in the evaluation of vendor compliance with these requirements. These requirements are specified in the purchase specifications referenced earlier. Quality Assurance also maintains a close working relationship with the Purchasing Department and the subcontractors to assure continuing conformance to the required standards of quality.

An assistant project engineer is generally assigned responsibility for each subcontracted functional component. He has the responsibility for closely following the progress of subassemblies at the subcontractor facilities and for test evaluation upon receipt of the subassemblies at Pratt & Whitney Aircraft. He initiates and coordinates design, purchasing, and vendor action on contracted items to assure timely delivery of acceptable components for the development program. For all major vendor-designed and supplied parts, Pratt & Whitney Aircraft has both component specialists and test facilities to ensure at least equal technical competence with the vendors.

Both the vendor and Pratt & Whitney Aircraft perform extensive bench testing. On major vendor components, Pratt & Whitney Aircraft usually compiles more actual test time than the vendor. However, the most meaningful reliability assurance information on vendor-supplied items will be that obtained on full-scale engine and subassembly rig tests performed in-house by Pratt & Whitney Aircraft.

Failures of vendor-supplied equipment during the development phase are subject to the same closed loop failure reporting and corrective action system as that followed for in-house designed and produced parts. Failure analysis information is supplied to the subcontractor for a cooperative effort in solving any problems that may arise. The assigned assistant project engineer is responsible for monitoring and feeding back to the Chief of Reliability pertinent reliability information that may be generated at the subcontractor's facilities.

Quality Assurance will maintain a close working relationship with the Purchasing Department to assure subcontractor conformance to the required standards of quality. Inspection procedures and requirements are established by Quality Assurance for all Pratt & Whitney Aircraft subcontractors. Inspection may consist of surveillance over a vendor's methods and procedures by a Pratt & Whitney Aircraft Quality Assurance Representative at the vendor's plant and/or inspection operations performed after receipt at Pratt & Whitney Aircraft.

The control of vendor component reliability is illustrated and described in detail in Volume III, Report B, Section III.

D. JTF17 RELIABILITY GOALS AND FEATURES

1. Reliability Goals

The reliability goals for the mature JTF17 engine are shown in table 1. The predicted reliability growth for the JTF17 engine is shown on figures 2 and 3.

The reliability goals were established during Phase II-C based on the actual service records of previous Pratt & Whitney Aircraft engines adjusted for the supersonic transport environment and the JTF17 design. Each major section of the engine was analyzed using the actual mature failure rates achieved in the current base engine (JT3D) and adjusted by correction factors accounting for the advance design features, complexity, and operational environment of the new power plant. This study is illustrated in the reliability apportionment Paragraph E.6. The review of commercial and military service data is described in Paragraph E.1.

An engine reaches maturity when the failure rates for the engine attain stable values. Based on previous experience, maturity of the JTF17 engine should be reached after approximately five million engine flight hours.

Table 1. JTF17 Reliability Goals Failure Rate per 1000 Engine Hours

1. Flight failure including augmentor failure - 0.040 (MTB FF = 25,000 hours)
2. In-flight shutdown excluding augmentor failure - 0.0344 (MTB IFS = 29,100 hours)
3. Premature engine removals (including flyovers)-0.20 (MTB PER = 5000 hours).
4. Augmentor failure (given the engine is running)-0.0056 (MTB AF = 178,600 hours).

Definitions:

FF - An inflight shutdown and/or the failure to obtain selected augmentor thrust.
IFS - Inflight shutdown excluding failure to obtain selected augmentor thrust.
PER - Premature engine removal including flyovers.

Flyover - A flyover is a premature engine removal which does not lead to complete overhaul. Expressed another way, if time since overhaul is not changed when the engine is reinstalled in the aircraft, the event is considered a flyover.

AF - Failure to obtain selected augmentor thrust given the engine is running.

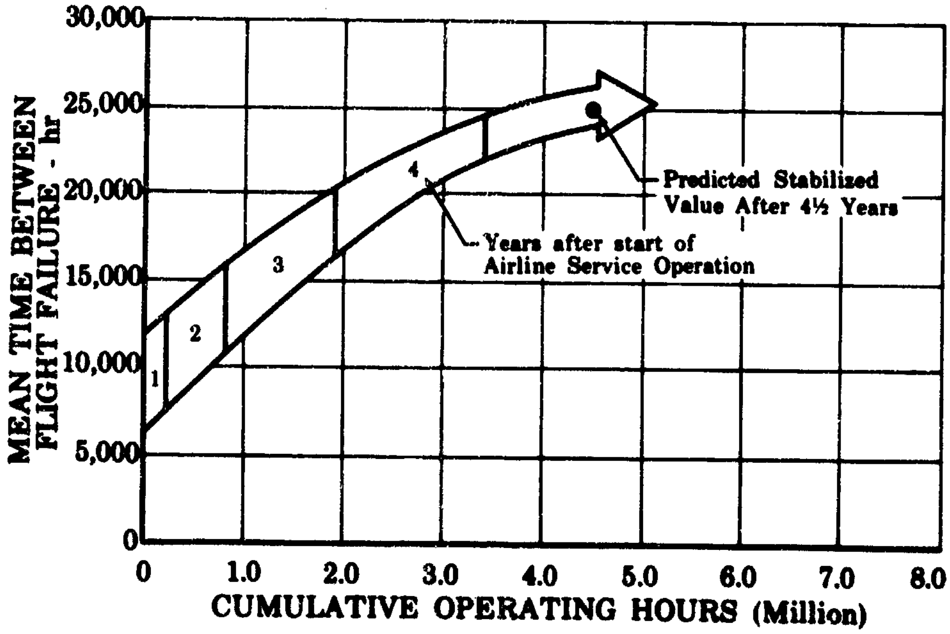


Figure 2. JTF17 Estimated Growth of Mean Time Between Flight Failures (In-Flight Including Augmentor) FD 17547 FII

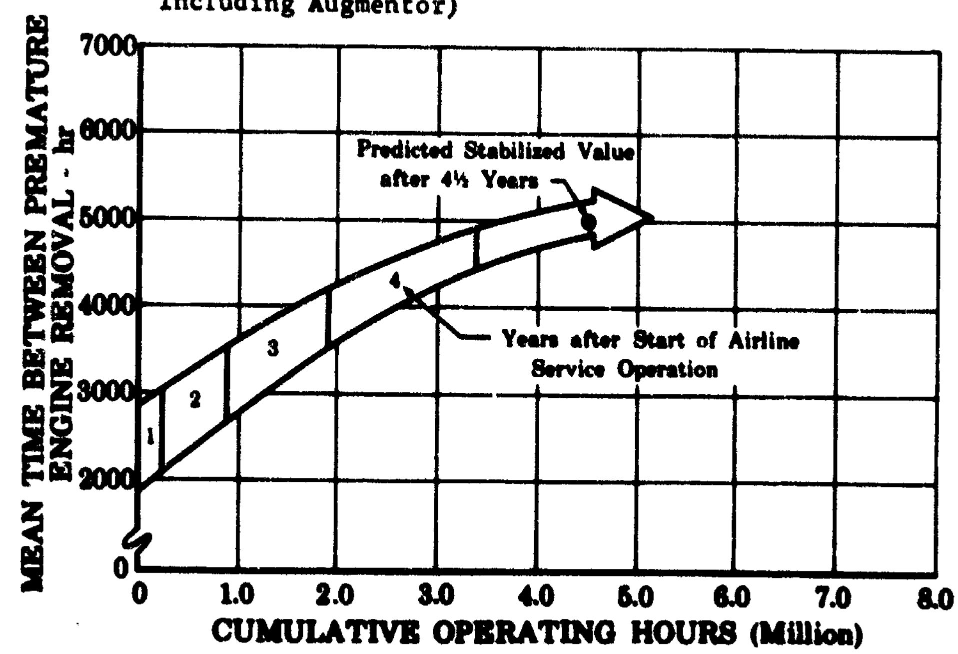


Figure 3. JTF17 Estimated Growth of Mean Time Between Premature Engine Removals Including Flyovers FD 17546 FII

2. JTF17 Reliability Features

To achieve the high level of reliability represented by the JTF17 reliability goals, new engine concepts have been combined with proven design features. This section summarizes the concepts and design features.

a. General

The use of advanced short length components with associated structural design simplicity is a key concept to improve reliability. The short engine length results in stiff low and high rotor shafts which are relatively insensitive to residual rotor unbalance. Thus, the short shaft reduces the amplitude of engine vibration and rotor bow. The shorter rotor construction also minimizes the number of bearing compartments and support structures required. The design uses four main engine bearings rather than seven. This decrease in the number of main bearings reduces the complexity of the engine, reduces the number of vibration modes, and eliminates complicated bearing alignment problems. The need for intershaft bearings has been eliminated, thus removing the related failure modes and assembly problems.

Another major design concept is the use of modular major component unit construction. Major sections of the engine such as the fan-low compressor assembly, high compressor assembly, burner-diffuser unit, low turbine unit, etc., are built-up as subassemblies and assembled to the engine as units. The high compressor and low turbine rotors are balanced within their cases with the stator vanes in place. This improved balancing procedure reduces the possibility of rotor shift or assembly error after balancing.

Improved inspection techniques are employed to ensure early detection of incipient failures. Borescope provisions are provided in the compressor, turbine, primary combustor and duct heater sections. In addition, the hollow low turbine shaft allows radioisotope inspection of internal components.

b. Fan

Overhung support of the fan rotor eliminates the need for a stationary structural vane section in front of the rotor. This in turn eliminates the requirement for an anti-icing system, eliminates a source of noise generation and pressure loss, and results in a better foreign object ingestion capability since there is no possibility of trapping material between the IGV's and fan blades.

The fan is initially assembled and balanced as a unit before installation in the engine to minimize vibration modes. The rotor is designed as a vibratory system to ensure there are no critical speeds or low-order disk and blade nodal frequencies in the running range. All rotor pilot diameters are closely controlled for concentricity, and stack-up is controlled for squareness to control unbalance. The rotor has enough wheel base between the hub snap diameters to assure squareness of the rotor on the shaft. The hub-to-shaft fits are designed to ensure that

the hubs will remain tight at all running conditions. (The hub and disk are integral, thus minimizing the number of parts as an aid in balancing.)

Rotor blades have been designed to withstand self-excited vibrations at high rotor speeds, self-excited vibrations at stalled flow conditions (flutter), and standing wave resonant vibration excited by inlet distortion. Moment-weight classified blades are used in the fan and both turbine units. This feature permits blade replacement in these units without the need for rebalancing the rotor. Double shrouds are used for torsional stiffness and blade incidence control, which are important in eliminating blade flutter. Different correction weight types are used for the dynamic rotor balance than are used for disk and blade assembly balance. This provides easy identification and ensures that the individual stage balance will not be lost if the rotor is torn down and reassembled. The fan assembly may be removed without disturbing the front bearing. This provides support for the low rotor shaft when the fan has been removed.

The trussed-hub fan rotor configuration is advantageous in obtaining necessary critical speed margin for the rotor with minimum weight. The truss system has been carefully designed to balance out all forces and moments to assure there is no rotation of the disk rims. The truss system is designed to maintain adequate axial pinch on the rim spacer to avoid axial separation in all situations including compressor surge. The disk has adequate burst and yield margin independent of the axial rim spacer.

A further advantage of the trussed cone design is the ability to remove bolt holes from critical areas of the design. Experience has shown that low cycle fatigue (LCF) life is greatly reduced by the stress concentrations caused by bolt holes. The cone disk concept avoids this problem by moving the bolt holes from the central structure to the disk support cone, which operates at a low stress level.

LCF is adversely affected at a disk bore or rim when high thermal gradients occur. The relatively compact radial configuration of the fan disks results in low thermal gradients. All surfaces of the disks are glass bead peened and the bolt holes in the hubs are polished to improve fatigue resistance. The low expansion coefficient and low modulus of titanium further decrease thermal stress, thus improving LCF.

The fan blading is designed to accept foreign objects without structural failure of the blades or vanes. Foreign object ingestion capability is a direct function of the overall blade strength and a correlation based on past experience in which blade bending energy is related to the blade root strength. Based on this criterion, the 1st-stage fan will have ingesting capability superior to the other Pratt & Whitney Aircraft production engines.

Both stages of blades are designed with two part-span shrouds for good structural integrity and resistance to foreign object damage. The total untwist moments caused by centrifugal loading on the blading are distributed between the two shrouds to produce torsional restraint and

damping during vibration. The use of double shrouds has a further advantage in that it improves the FOD ingestion capability. The forces resulting from ingestion of large objects are distributed to adjacent blades by the shrouds, thereby limiting the resulting stresses.

The blades are mounted in a single dovetail slot in the disks and are retained axially by locking rings. The 1st-stage blade is retained axially in the disk by the rim spacer in the rear and by a lock ring in the front. The 2nd-stage blade is retained by a lock ring in the rear, to prevent fore and aft movements. The advantages of this locking system are: (1) all blades are locked simultaneously, (2) no loads are placed on the retaining rivets, and (3) there is redundancy in the locking as all the rivets must fail before the ring can disengage. Tubular rivets are used for easy installation and removal, and to prevent damage to the disk.

Root attachments use radius undercuts at each end of the bearing face. The undercuts greatly increase the life of root attachments by eliminating the high point contact loads that can occur when the corner radii of the disk and blade interfere. If wear, local yielding, or redistribution occurs in the root attachment, the undercut also prevents the buildup of a high point on the neck radius. The 1st-stage hub spline and the dovetail slots of both disks are treated with graphite varnish to prevent surface galling. Rotor tiebolts are hydraulically preloaded, which allows the bolt to have a high tensile load without torsional stress. This method of assembly ensures uniform stresses in the bolts for maximum life, as well as uniform preload on the snaps for positive seating and minimum vibration.

The fan rotor is designed to meet instantaneous transient loads caused by bird ingestion and compressor surge; it has sufficient yield margin to allow for fan overspeed resulting from a duct heater blowout with the duct nozzle failed open. The rotor is also designed to meet various types of failure criteria, such as a 10% adjacent blade loss and confine the failure to relatively small masses such as blades and vanes and maintain rotor integrity. In the event of failure, such as blade loss, the 2nd-stage is not completely dependent upon the tiebolts to support the disk. Both disks are mounted on double piloted hubs and are not dependent on the tiebolts alone to maintain the integrity of the rotor. Redundancy exists, considering the blade loss criteria, in that not only are the bolts designed to take the resultant moment, but the pilot diameters have adequate wheel base to give moment support. If all the tiebolts should fail, the disks are still mounted on the double pilots and retained to the shaft by the spanner nut.

An inner platform seal ring at the stator ID and a knife edge seal on the first stator retard recirculation leakage around the stator. The seal lands are of serrated construction to provide better sealing than conventional solid lands because of the tighter permissible running clearance. This feature improves reliability by reducing the effect of shear forces and heat generation in the event of radial rubbing during an abnormal operating condition. The 1st-stage vane knife edge seals are not carried on the 2nd-stage disk or spacer to preclude transmitting the heat generation associated with seals into a major structural member.

Commercial engine experience has indicated that 1st-stage blades and vanes are susceptible to foreign object damage in service. For this reason, airfoils of the 1st and 2nd stator are forged and riveted at both the inner diameter and outer diameter of the stator to obtain damping and permit easy replacement of individual vanes. The stators behind each blade row are axially spaced to minimize a source of blade-to-vane passing frequency noise. Inlet guide vanes forward of the fan rotor were not used, eliminating one source of blade-to-vane passing frequency noise.

The double-wall front case provides increased reliability over a single wall construction. The outer wall carries the front mount loads back to the intermediate section. The inner wall provides an airflow path over the fan blade tips. High local radial deflections in the front engine mount case are isolated from the tip clearance region by the double wall construction. This feature permits the shrouds to maintain close clearances with the fan blades without being subjected to the radial deflections of the mount. A smaller blade tip clearance not only improves the steady-state performance, but also the distortion tolerance of the fan.

The wall thickness of the fan case has been designed to ensure blade containment. The case has been designed to satisfy the blade energy criteria and, in addition, to satisfy the extreme shear conditions that result from the larger parts and higher tip speeds characteristic of this engine. Shear criteria have been used to size the fan case. The shear criteria were also used for both the compressor and turbine sections as well as the energy criteria.

None of the details in the fan module can be installed backwards, minimizing the possibility of failures due to assembly errors.

c. Intermediate Case

The reliability of the intermediate case has been improved by reducing high stress concentration areas. Butt welded construction, integrally machined, contoured standups and tapered wall thickness to weld joints are employed. This construction has the decided advantage of having all welds loaded in simple tension or compression. Areas with combined bending stresses will occur in parent material away from the welds and heat-affected zone.

The butt-welded joint and the elimination of fillet welds with inherent corner stress concentrations results in a more reliable case. The probability of cracking associated with fillet welds has been eliminated since there are no fillet welds on the intermediate case. To further reduce the possibility of cracks, the diaphragm loads from the bearing compartment are fed into the struts away from the leading and trailing edges where there is a natural stress concentration. If cracks should occur, they are much easier to rout out and clean preparatory to welding; thus, ensuring a successful repair.

The bearing compartment has been designed as a separate and removable part with the rotor bearing supports independent of either the compartment or the intermediate case. This simplifies the intermediate case structure

and permits the removal of close toleranced bearing housings and/or supports if weld repair is required in the case. It also makes those parts most subject to damage replaceable. Replaceable bushings or liners will be used at all points where wear might occur and cause damage to the main case.

d. Compressor

The compressor consists of a variable inlet guide vane and six stages of compression. The compressor rotor is on a separate, high speed spool relative to the fan. This permits the fan and the compressor to rotate independently at the most efficient speed relationship for each rotor system. The variable inlet guide vane provided at the compressor inlet serves the dual function of braking the high rotor and provides some compressor matching over the operating range. The braking of the high rotor reduces the high rotor speed during windmill operation, to lessen the likelihood of lubrication failure.

The high compressor inlet guide vanes are one-piece forgings. No welding or sheet metal is used, thereby eliminating the problems associated with this type construction. These vanes are linked to an externally mounted actuator by a torque rod, bell crank arm, and synchronizing ring. In addition to utilizing a minimum number of parts, the entire linkage is deflection limited with low stresses, thus virtually precluding the possibility of primary failure.

The compressor rotor consists of six bladed disks and a front and rear hub which are held together by axial tiebolts. To achieve good balance characteristics, a minimum number of parts are used in the main rotor structure and long pilot engagements have been incorporated on all rotating parts.

Disk spacers are an integral part of the 1st, 3rd and 5th compressor disks. The integral arms incorporate thickening or "barrelling" of the spacer directly under the disk spacer snap to increase the LCF life of the parts. In addition, the flanges on the integral arms incorporate additional holes between the compressor tiebolt holes. These extra holes provide a uniform circumferential spring rate for the flange to prevent radial LCF cracks due to abrupt thermal changes. The rotor disks are vibratory barrel finished to eliminate any stress risers.

Compressor disk cooling is provided to minimize low cycle fatigue gradient effects. The cooling air is introduced to the inside of the rotor by anti-vortex tubes between the 2nd and 3rd disks. The single backbone rotor design enables all disk surfaces to be scrubbed by cooling air at a rate commensurate with desired metal temperature transient response.

The 1st compressor blades incorporate a midspan shroud for torsional stiffness, and to damp any possible first bending mode vibration excited by the widely varying inlet condition. The remaining blades are unshrouded. The blades are retained axially by a double locking device. The aft load is resisted by a tang made integral with the blade; the forward movement is prevented by a wire blade lock incorporating four shear areas. The blade platforms are interlocked, therefore adjacent blades support each other in resisting axial movement. In this way a single blade impact will receive additional support from adjacent blades.

The tang and blade lock system used to retain the compressor blades replaces the troublesome sheet metal tablocks that are prone to straighten after long periods at elevated temperatures. Before a blade can become loose it is necessary to shear four wire cross-section areas.

Blade dovetails for the 3rd, 4th and 5th stages are undercut similar to the fan stages for bearing surface control and increased life. The 6th, 7th and 8th stages do not require this undercut due to the very high toughness of the waspaloy blades. Blade root disk slots of the first three stages are treated with graphite varnish to prevent galling. These blades are shot peened at the root attachment and glass bead peened all over to increase fatigue strength and resistance to stress corrosion. Blade roots on the last three stages are shot peened to improve fatigue strength and silver plated to prevent galling.

All compressor vanes are retained and supported by box shrouds at both the inner and outer diameters. This double (guided cantilever) support provides positive retention of damaged airfoils and avoids vibrational problems of single ended vane supports. The guided cantilever stators have redundancy of an additional support in the event of a cracked airfoil since the design provides positive retention of each end of a cracked airfoil.

All compressor cases are continuous rings to minimize warping. This also reduces assembly difficulties at overhaul where increases in blade tip clearances can result in performance losses.

Interstage rotating knife edge seal lands are of the machined circumferential serration type. The seals are restrained to prevent axial movement, and torque is transmitted through tangs to prevent rotation and wear. To preclude replacement of expensive parts having other functions, the knife edge seals are not made integral with the spacers. The seals were eliminated from the rotor aligning joints as a precaution against balance problems caused by unnecessary flanges.

Spacing between rotating and static members of the high compressor is such that, in the event of a large rotor shift, blade and vane engagement occurs before high stressed rotor parts can rub stationary members. This feature eliminates the possibility of a disk rupture due to scoring (rubbing) by an adjacent stationary part. Foolproof provisions are included to prevent failures due to assembly errors.

e. Diffuser Case

The diffuser case is a weldment consisting of the inner and outer machined forged walls and 12 cast struts, which are butt-welded to airfoil-shaped standups integrally machined into the case walls. Stiffening rings are used at the leading and trailing edges of the struts to distribute the strut loads into the case. The boss connections associated with the diffuser case are butt-welded to standups integrally machined into the forgings.

The fabrication of the diffuser case has the same reliability advantages as the intermediate case. The elimination of the fillet weld type construction significantly reduces the probability of cracking in the diffuser case. Loading all welds in simple tension or compression and employing tapered wall thicknesses at weld joints will further minimize weld cracking by eliminating stress concentrations and adverse loading.

f. Annular Combustor

The ram-induction annular combustor provides significant reliability advantages over the can-annular concept used on current engines. The problems associated with the crossover tubes and burner can clamps have been eliminated because these items are not required on the annular combustor. A reduced circumferential temperature gradient, fewer hot spots and a greater cylinder flexibility are provided by the annular combustor. These features contribute to a reduced incidence of low cycle fatigue cracking and thereby reduce the probability of failed pieces causing turbine damage.

The ram air scoops are contained in modules suspended from the combustion chamber cases. This modular concept minimizes the structural and thermal problems. Because this type of combustor does not rely on a static pressure differential across the combustor walls (as does the conventional combustion chamber), the pressure loading of the scoop modules is much lower. The high velocity flow over the scoop modules and through the ram scoops provides basic cooling by convection with supplemental cooling supplied to those surfaces directly exposed to the hot gases. Additional air is allowed to spill over the scoop edges to provide an insulation blanket between the hot combustion gases and the scoop walls. The air film also provides a wash to prevent carbon accumulation, thereby reducing turbine airfoil erosion.

The modular concept used in the annular combustion chamber minimizes the buckling load on the outer combustion chamber wall. Use of modules effectively breaks the external pressure load on the wall into a number of small inward loads that are sustained by the hoop loaded outer case.

The concept of supporting the combustor and transition duct from the inner and outer burner case walls avoids thermal growth differential resulting in supporting and sealing problems by allowing the modules to flex and move with the case. This concept also allows removal of the entire annular combustor or replacement of individual modules without removing the turbine.

The convectively cooled transition duct section of the primary combustor is formed by an inner and outer shell section consisting of 15 circumferential segments in the inner shell, and 24 in the outer shell. The higher temperature gas path wall of these modules is attached to the cooler structural wall by a bushing and fastener arrangement. This type construction permits the hotter wall to float in both the axial and tangential direction to accommodate the thermal growth differences between the two elements.

The fuel system for the annular, ram-induction combustor chamber consists of 24 individually removable nozzles. The fuel nozzles are housed in individual supports mounted on the diffuser case and are retained and positioned by a flange. This construction permits ease of inspection or replacement of nozzles. The air sweep guide has been incorporated as part of the nozzle to reduce turbine erosion by preventing carbon accumulation on the nozzle tip.

g. Turbine

Positive failsafe features have been incorporated in the turbine design to prevent disk burst as a result of a primary failure of another part. Component arrangement is such that excessive axial rotor shift will cause blade airfoils to contact vane airfoils, thus reducing rotor speed prior to any disk-spacer contact.

The 1st-stage turbine disk has an integral arm at the bore, which eliminates the need of a separate shaft to secure it to the high pressure compressor shaft. This allows better alignment due to a reduction in number of joints, which also improves balancing and vibration characteristics. The design approach has an additional advantage of avoidance of holes in high stress regions, thus improving LCF life capability. The 2nd-stage disk also avoids holes in high stress regions. It is attached to the low rotor shaft by an integral arm. The 3rd disk being cooler contains a conventional bolt circle which secures it directly to the integral hub of the low turbine shaft.

Improved material coatings and cooling schemes were incorporated to minimize the effects of elevated turbine inlet temperature. The disks are cooled by compressor discharge air to maintain a low and uniform disk metal temperature. This improves low cycle fatigue life by minimizing disk temperature gradients because of gas stream temperature variations during engine starts and shutdowns, accelerations and decelerations, as well as during aircraft ascent and descent transients. The turbine airfoils combined thermal and centrifugal stresses do not exceed the elastic limit, and therefore, no LCF problem will be experienced.

The disk and blade attachment point is cooled by the flow of blade cooling air through the manifold immediately under each blade fir tree. Blade cooling air is orificed on the blade at the cooling air entrance. Thus airfoil damage cannot affect the cooling flow to the remaining blades. The portion of the blades inside the platform is protected from excessive heat pickup due to radiant heating by heat shields fore and aft just inside the platform, and from convective heating by the coverplate on the front (1st-stage), which seals against hot air leakage across the disk. The twin labyrinth seal between 1st- and 2nd-stage disk is insensitive to transient thermal conditions ensuring a continuous flow of cooling air to cool the disks.

Each blade/disk combination has been designed to have its natural frequency above the 2E excitation and to cross over all other excitation lines at speeds outside the normal running range. A source of integral order excitation in the turbine has traditionally been the number of burner cans. This source has been eliminated by the annular combustor.

The axial spacing between the third blade and the exit guide vane has been set to avoid the excitation that is fed upstream from the turbine exit guide vanes. The 1st-stage blades are not shrouded. Vibration damping is accomplished with a system of toggle weights.

All vanes are constructed in pairs with a common platform and attachment. This arrangement provides an important reliability feature. In the event of burnthrough of an airfoil, the remaining airfoil portions are retained by the adjacent airfoil and platform and attachment structure. The bending moments in the airfoils are reduced because the interconnecting inner platform convert the airfoils to a guided cantilever design. The larger outer platforms give a longer attachment wheelbase and reduce the loads induced in the outer support structure.

h. Vibration

Careful attention has been given to engine vibration resulting from the interaction of the rotating and stationary structure since this is one of the primary causes of premature engine removal.

(1) General

Engine vibration amplitude is usually maximum at a critical speed where an engine rotor turns at a speed that is equal to any of the family of engine natural frequencies. Engine vibration is excited by the centrifugal load acting on the bowed rotor. The amplitude of engine vibration and rotor bow are limited by rotor stiffness and the damping provided by the friction forces acting to resist vibratory motion of mechanically joined parts of the engine static structure.

The 20% margin required on rigid bearing critical speed provides shaft stiffness that is insensitive to residual rotor unbalance because amplification of shaft bending is kept to a minimum. Further advantages of adhering to a 20% margin are that rotors are stable under unsymmetric pressure loading. Circumferential variations in radial pressure on labyrinth seals or on rotor stages, caused by slight out-of-roundness of lands and shrouds, cannot then cause unstable rotor whirl. Axial pressure fluctuations over part of the flow annulus, in the event of surge, produce negligible shaft deflection.

(2) Rotors

The high-speed and low-speed rotors are the exciting mechanisms that cause rotary loads on the bearings. Each rotor is supported by two bearings, which eliminates the inherent alignment difficulties associated with three-bearing supported rotors. This alignment has been a primary factor in excessive unbalance and premature engine removal in past engines. The two bearing system eliminates rotating forces produced by a misaligned three bearing system.

The short engine design, coupled with the gyroscopic stiffening inherent in the large diameter fan, results in a lightweight and stiff low-speed rotor. Similarly, the high-speed rotor shaft is light and stiff because of the short distance between bearings and the gyroscopic stiffening resulting from the overhung turbine.

The advantage of a stiff rotor is that it is relatively insensitive to residual rotor unbalance. Minimal rotor excitation results because of small rotor bending. Therefore, the total unbalance is primarily a function of initial unbalance, which can be controlled by close machining tolerances and balancing of the rotor disks, shaft, and rotor assembly.

All parts that comprise the primary rotor structure are provided with positive radial pilots, and are held together by a number of uniformly loaded tie rods that ensure adequate clamping action. Critical joints in the rotor assemblies are seated (with the multi-tie-rod construction) prior to balancing. Proper seating and the clamping action provided by the tie rods ensures that there is no shift in the relative position of adjacent parts during engine operation. Even with removal and replacement of the fan section, balance is maintained, because the fan section is dynamically balanced as a separate package.

(3) Bearings and Supports

The engine rotors are supported on three separate bearing support structures. The intermediate case supports both thrust bearings. The high-rotor rear bearing structure is supported from the primary gas generator diffuser case, and the low-rotor bearing is supported by struts in the turbine exhaust case. The bearing support structures transmit shaft loads to the primary gas generator cases.

The intermediate case support struts and primary gas generator aft support transmit loads to the outer case. The aft support provides additional stiffness to the primary gas generator case with the advantage of frictionally damping vibratory loads.

The bearing support structures are sized to adjust critical speeds away from speed ranges at which long time operation occurs. No critical speeds occur in the cruise ranges of the rotors. The critical speeds that do occur within the operating range have low shaft bending and high damping from the cases.

The No. 4 bearing support has been designed with a slotted cylinder spring integral with the structure, which is relatively flexible, in order to reduce both shaft bending and the transmission of vibration.

i. Duct Heater

The duct heater diffuser is formed by the inner and outer cases, which are connected by eight airfoil-shaped struts. Butt weld construction is used throughout the fan diffuser to ensure reliability, repairability as well as to provide readily inspectable weld joints with reduced stress concentration. The inner and outer walls of the combustor support case are connected by eight equally-spaced airfoil-shaped struts. Stiffening rings are used at the leading and trailing edges of the struts to distribute the strut loads into the case. Butt-welded construction throughout the basic structure minimizes weld shrinkage, distortion, and built-in stress concentration points.

The duct heater is a two-zone annular ram-induction combustor. In the ram-induction combustor region (Zone I) fuel is supplied by 40 uniformly-spaced nozzles. Ignition in Zone I is achieved by electric spark igniters. The minimum fuel/air ratio has been set at 0.002 for ignition. At this level there will be (1) negligible fan duct pressure and airflow transient during duct heater lightoff, (2) no change in aircraft inlet setting during duct heater lightoff, and (3) smooth thrust transition at lightoff. Zone II fuel, which is introduced through 270 uniformly-spaced fuel injectors, ignites spontaneously from the Zone I combustion gases with no significant pressure change.

The Zone I fuel system is composed of individually removable nozzles. A series of holes allows cooling air to be aspirated inwardly to wash the nozzle face and prevent fuel coking and carbon accumulation. Each fuel nozzle is protected from fuel contamination by a strainer located in the nozzle cap. Strainers can be inspected, cleaned or replaced without disassembly of the Zone I fuel manifold.

The combustor utilizes the module concept. Two scoops and a base plate make up one module, which can be individually removed while leaving the inlet fairing and Zone I fuel nozzles intact.

The duct heater outer liners serve two primary functions. First, being convectively cooled thermal barriers, they contain the high temperatures of the combustion gases. Secondly, they provide acoustic absorption which stabilizes combustion and reduces engine noise. The outer modules have transverse convolutions to provide longitudinal flexibility and to relieve thermal stress. The resulting increased transverse stiffness also increases the segments buckling limit. The inner duct wall incorporates a boundary-layer bleed for inner wall cooling air. The radial square-spline aft support allows for radial and axial expansions.

Thermal stresses are eliminated by using the modular construction for the Zone I annular combustor; the modules are suspended individually and allowed to grow to relieve stresses when the duct heater is in operation.

Component cooling by relatively cool fan discharge air, ensures component temperatures at values commensurate with long life.

j. Exhaust Nozzle

Backflow between the synchronization ring and the outer duct wall is prevented by a series of pressure balanced sectors that form a dynamic ring seal. Adjustable synchronization ring rollers remove looseness and backlash from the system and provide accurate nozzle positioning and feedback to the control system. The synchronization ring, rollers, and support are designed to withstand stalled actuator cocking loads without overstress of any part.

There is continuous cooling flow circulation of fuel through the actuator housing and rod. This prevents stagnation and overheating of the fuel and also prevents heating of the actuator rod with subsequent thermal shock to the rod seal package when extended and retracted. The

seal leakage of the actuators is either returned to pump interstage, or directed to the overboard drain; this fire-safety feature prevents leakage inside the nacelle.

Blowoff and radial aerodynamic loadings on the flaps are resisted by tangential and axial stresses in the basic fixed structure and not by high hydraulic forces or by localized bending loads which could shorten fatigue life. These low actuation forces result in a hydraulic system with low pressure requirements, and low-stress actuator mounting and attachment points.

In the event of complete hydraulic system failure, the nozzle is designed to open under aerodynamic loading. This failsafe position will allow the use of maximum duct heater for maximum engine power, as well as zero duct heat and throttled engine power.

Wear resistant liners for the flap segment positioning tracks and synchronization ring tracks are used. Wear and oxidation resistant coatings for the actuator rod, seal, and flap surfaces, and plug outer surface are used. Wear resistant materials for the actuator, rod end bushings, and flap and synchronization ring rollers are used.

k. Reverser-Suppressor

The reverser-suppressor is failsafe under all conditions. The features that accomplish this include the following items:

1. Throttle-reverser interlock system
2. Elimination of high pressure on actuator seals
3. Pressurized actuator required only for thrust reversing
4. Aerodynamic balancing of clamshell doors to reduce actuator forces and assure failsafe positioning in event of hydraulic failure
5. Integral aerodynamically-actuated system to provide all forward flight configurations.
6. Automatic mechanical lockout of reverser system at high Mach numbers.

All main structural members are designed for compression or shear buckling stresses. These are well below the allowable yield stresses, thereby eliminating or reducing the creep life and fatigue considerations for metals at elevated temperatures.

The inside "hot" surface of the reverser-suppressor is of a non-heat-treatable nickel base alloy for maximum life at elevated temperatures. This alloy is not subject to aging when maintained at temperature for long periods and is easily weld repairable.

The three basic modes of the reverser-suppressor are basically aerodynamically and mechanically stable and do not require continuous or oscillatory motion to achieve maximum performance. Each mode change is smooth and positive, and only four motions occur during a typical flight. This results in a reduction of wear on the moving parts. In addition, all mode changes, except aborted takeoff, occur during periods of low load conditions, a feature that increases the dynamic life of

each of the moving parts. All parts subject to wear are separable from the reverser-suppressor structure, allowing use of special high-strength, wear-resistant materials without compromising the main structural integrity.

The hydraulic reverser actuator system and clamshell tertiary air door interlock system is modular and is mounted in a separable framework that can be installed, removed, or bench tested as a package.

l. Shaft

The main shaft is carefully protected from failure as a consequence of the failure of some other engine component. All main shaft thrust bearings have been designed so they are not directly mounted on major torque carrying shafts. Main shaft splines, through which the turbine torque is transmitted, have been located a safe distance away from the main shaft bearing. Thus the torque-carrying capacity of the spline will not be seriously affected by heat generated as the result of a main thrust bearing failure.

m. Bearings

The engine has been designed with a simple twin rotor system with two bearings supporting each shaft. The bearings are of single row, balanced cage construction, designed to prevent skidding. Thrust bearings are mounted on a non-torque portion of the shafts. The two thrust bearings are on the forward end of each rotor, to allow the more heavily loaded thrust bearings to operate in the cooler front section of the engine.

The single row ball thrust bearings have the following advantages over the double row type previously used, as they do not suffer from unequal load sharing due to manufacturing tolerances or thermal growth. The single row has fewer pieces in the assembly with consequent higher reliability.

The problem of bearing races spinning has been eliminated by the incorporation of antitorque features. All outer races are flanged and bolted, to prevent rotation. All rotating races are limited to the inner race, and incorporate tight fits with positive retention on their associated shafts. All the retaining spanner nuts on the main shaft use a specially designed lock washer that is installed after the nut is torqued and then secured by a locking ring. This locking device eliminates any chance of damage to the locking tangs and ensures a positive lock.

Potential fatigue failures have been reduced by using bearings made from consumable Vacuum Melt material to avoid spalling that results from sub-surface inclusions in the material. The bearing design minimizes the heat generated due to churning of the oil by supplying the major portion of the oil through the inner race for more efficient cooling. The design prevents incorrect assembly of the bearings.

n. Seals and Lubrication System

The bearing compartment seals are integrated into an advanced seal system that isolates and continually bathes the bearing compartments in cool fan discharge air. This feature, coupled with a design that eliminates rubbing seal face contact provides excellent durability.

Use of an overboard vent system prevents oil from entering the main gas generator stream thereby eliminating the danger of oil fires or cabin air bleed contamination.

The hydrostatic seal system has excellent wear characteristics because the seal surfaces are not in contact during operation. In addition, hydrostatic seals have the redundant capability to operate as a conventional carbon rubbing seal in the event of low supply air pressure. This ensures positive oil retention at any point in the flight envelope.

The seal plate is cooled with a positive flow of oil through closely spaced holes within the plate to retard wear in the event of seal ring and seal plate contact.

The lubrication system centrifugal de-oiler is of the "pin-wheel" type which is extremely effective in oil separation and produces a low pressure loss. This minimizes oil loss over a broad range of breather airflow and pressure.

The struts in the intermediate case are sized to accept a tower-shaft enclosed in a sleeve to maintain a nominal air space around the sleeve to assist in preventing oil coking.

o. Gearbox

The main accessory gearbox mounting system provides gearbox retention without inducing stresses in the gearbox or accessories because of mechanical or thermal deflections of the engine.

Gearbox lubrication is supplied directly from the main engine oil system. Oil is distributed to the gears, bearings, and seal faces for lubrication and cooling. All accessory drive splines are provided with positive lubrication to reduce wear and binding. In addition to the oil that is delivered to the bearings and seals, sufficient oil is dispersed throughout the gearbox to cool the housing walls to a maximum housing wall temperature of 450°F.

All rotating bearings are designed so that the inner race rotates. The inner races have tight fits and positive retention on their associated shafts. All outer races are either flanged and bolted, or are set in replaceable bolted steel liners with closely controlled fits and mechanical locking to prevent rotation. Thrust bearings are provided on all shafts, and provision for bidirectional thrust is provided where necessary. All bearing liners are mechanically retained in the housing casting to minimize gear and bearing misalignment due to load and thermal deflections. Bearings are set as far apart as possible to minimize misalignment due to tolerance and thermal deflection.

The balanced tooth concept is used for all gear design. With this concept, the endurance beam strength of the pinion and gear in a mesh is equalized to give maximum possible life. Tooth form layouts are made to establish the best tooth properties for the design application with respect to wear and strength, contact ratios, and the ability to run without interference under adverse mounting conditions. All gear tolerances are governed by specification PWA 350 to ensure accuracy of the gear teeth with respect to tooth form and tooth errors that may affect dynamic tooth loading. All gear teeth and gear webs are shot peened to increase fatigue life.

The fuel control is driven by a quill shaft to prevent possible external loading due to misalignment or to differential thermal expansion. All accessory drive splines are provided with positive lubrication to reduce wear and binding. Accessory pads are sealed with cartridge-type carbon face seals. All seals are accessible for inspection or replacement without gearbox disassembly.

p. Lines and Fittings

Tube stresses, clamping locations and routings are established by extensive calculations made by high speed digital computer programs. These programs are used for all fluid systems, and provide a quick and accurate means of routing tubes for the best compromise of short lengths, while maintaining sufficient flexibility to keep stresses low and uniform throughout the tube. The lines are designed with support brackets located to keep tube resonant frequencies well above engine frequencies.

Integral tube connectors are used extensively to ensure maximum tubing system reliability. These connectors are machined as an integral part of the tube to provide maximum fatigue strength.

The AN type threaded joints utilize a thin nickel gasket between the ferrule and connector. Flange connectors incorporate Inconel X spring type "K" seals. These seals, both of which have excellent thermal shock capabilities, have been developed to a very high level of reliability and low incidence of leakage.

Sliding support brackets are used where movement must be allowed to account for thermal expansion. These brackets are designed to allow the tube to move in the direction that reduces the tube stress as the engine thermals change. Static (fixed) brackets are used at support points that require no movement due to thermal growth. Careful consideration of strength and natural vibration frequency is given in designing both static and sliding brackets. The combination of sliding and static brackets is used to shift the stress from a critical area, i.e., connectors and component fittings to maintain low uniform stresses throughout the tube length. Extensive experience has proved the combination of metals and coatings used for the sliding brackets have excellent wear life and strength properties.

The tubing clamp standoff eliminates clamp wear on the tube at the point where the clamp attaches the tube to a static or sliding bracket. The design of the standoff eliminates highly stressed sections at tubing

support points by permitting the tube to flex through the standoff instead of forming a rigid local tube section and by dampening the tube vibration. The clamps used at standoff locations are modified MS type clamps providing thicker cross section and closer toleranced inside diameters for increased reliability.

Systems containing two or more of the same type components such as nozzle actuators, fuel nozzles, etc., manifolded together, are designed with "flow-through" fittings to minimize the number of joints required. The reduced number of connections and tubes increases engine reliability.

q. Controls and Accessories

The control system provides redundant compressor inlet temperature sensors, and burner pressure and fan pressure sensors for increased reliability. Reduced fuel flow is automatically provided by the control system to prevent compressor overspeed and turbine overtemperature in the event of system malfunction. The system provides failsafe plateaus on the speed scheduling cam, failsafe contours on the metering valves, and limit stops on the compressor inlet temperature, burner pressure, and duct pressure servos to provide safe operation in the event of failure in extreme positions. Interlocks are provided to prevent control power lever motion to reverse or forward unless the reverser is in the correct position. Automatic duct heater shutoff is provided in the event of a blowout. In the event of an inlet unstart or compressor surge immediate reduction of fuel flow to a selected minimum is provided which will prevent turbine overtemperature in response to burner pressure decay rate.

(1) Unitized Fuel and Area Control

The basic engine control (unitized fuel and area control) includes the gas generator and duct heater fuel controls and the duct exhaust nozzle area control. The unitized concept increases reliability by using a common control computer, simplified engine plumbing and component mounting by locating the various controls in a common housing. Additional reliability features are as follows:

The critical computing portions of the control does not carry any of the mounting or plumbing loads and is supported entirely by internal members and enclosed by fuel containing vessels.

Bolts with a hardness in excess of 38 Rockwell C are not used due to susceptibility to stress corrosion. All screws with the same thread size are the same or sufficiently different in length to ensure that the screws cannot be misused.

Seals have low installation forces. Metal chevron seals are not used for dynamic applications. Elastomeric seals of a high temperature fluorosilicone or fluoricarbon compound are used where seal temperatures are less than 500°F.

Adequate wall sections to maintain stresses and deflections within safe limits are preferred over ribbed sections since

uniform sections are easier to fabricate and less susceptible to high stress concentrations due to pressure loading or thermal gradients.

Housing temperatures are maintained at desired values by internal fuel cooling with care being taken to ensure this fuel does not impinge upon control linkages to cause scheduling errors.

Sensing compressor inlet temperature and transducing the signal to a fuel pressure is accomplished on a redundant basis.

Servos are fabricated as modules, where possible, to permit individual calibrations and prevent erroneous servo performance which might result from unequal thermal effects. A servo piston will not operate in a bore that is common to two housings. Means are provided to measure servo piston travel during bench calibrations, where practical.

Large hard-surfaced cams are used to provide signal-to-error ratios as high as possible. Wear points of linkage systems incorporate hardened inserts for bearings to minimize wear. Also, linkage systems incorporate ball bearings at the critical pivot points. Linkage system design is directed toward obtaining links that have as little deflection as practical.

Replaceable wear sleeves for major valves and pistons are utilized. Retention of such sleeves prevents movement that would result in erroneous control performance.

Chrome surface rubbing on another chrome surface is avoided. Deep nitriding for case hardening is discouraged due to susceptibility to chipping. Liquid nitriding is the preferred method of case hardening.

The system is designed to tolerate fluctuations in the reference and supply pressures. Pressure signals cover as large a range as possible to maintain the signal-to-noise ratio as high as possible.

Fine grit vapor blasting has been beneficial in deburring sliding or rotating steel parts and is used extensively.

Half-ball valves, spool valves, and servos of the null position type have all parts grounded to a common surface so thermal gradients do not cause a change in null location.

Pressure regulating valves have a variable sensitivity controlled by the contour of the port or valve so stability and control of pressure is uniform over a large fuel flow turndown ratio.

Servo system loops are closed at the output of the servo wherever possible, to keep servo accuracy at an optimum.

Temperature-sensitive devices used for compensating for changes in fuel density are located so the fuel sample is typical of that which is passing through the metering valve.

The engine inlet temperature sensor has a time constant goal of 3 seconds or less to ensure that control scheduling accuracies are maintained during transient operating conditions.

(2) Gas Generator Fuel Pump

A filter is incorporated at the boost stage discharge and a mesh screen is located within the hydraulic and control bypass return flow path to the gear stage, unitized control, and fuel injection nozzles. Bypass valves are provided around both of the filters to provide a flow path in the event the filters become contaminated. Indicators are incorporated that produce a visual indication if the filter pressure drop approaches the bypass condition.

A bypass valve is incorporated around the boost stage which opens in event of impeller blockage to provide a low restriction flow path to the high pressure section. This will permit the pump to continue to operate on the main stage alone. A relief valve is included at the pump discharge which opens to prevent excessive discharge pressure in the event of downstream malfunction.

The pump drive spline is lubricated by oil supplied under pressure from the engine oil system to reduce wear.

(3) Duct Heater Fuel Pump

The pump assembly consists of an inducer boosted centrifugal pumping element which is driven by an axial flow air turbine. Use of this variable speed capability permits operation of the pump at reduced speed for most of the flight regime. The speed is modulated to produce only the pressure rise necessary to provide the duct heater fuel flow required for the specific altitude and Mach number conditions.

The principle benefit of this system over a gearbox driven pump, which must be operated at higher than the required speed and fuel flow for most of the flight regime, is the significant reduction in heat added to the fuel by the pump.

Secondary benefits are improved reliability and durability resulting from the reduction in operating time at maximum speed and stress.

Turbine drive air is supplied from the compressor discharge bleed manifold and is regulated by a duct pump controller. This controller varies pump speed as required to produce only the output pressure demanded by the fuel control.

Overspeed protection is provided by a vortex venturi at the turbine discharge. This device, which does not require moving parts or a pump speed sensor, aerodynamically limits pump overspeed by creating a back pressure at the turbine discharge if an overspeed condition develops,

thereby reducing the available turbine horsepower. Increased turbine discharge swirl angle associated with overspeed initiates a vortex which produces an aerodynamic restriction to turbine discharge air flow.

Fuel is used to lubricate and cool the bearings, seals, and inducer speed reduction gears. This feature eliminates the need for an external oil supply and scavenge system, and also precludes the possibility of depleting or diluting the engine oil supply in the event of a turbine end or impeller end shaft seal failure.

(4) Hydraulic Pump

The hydraulic pump is an engine driven, reciprocating multiple piston fuel pump that is utilized to provide the engine hydraulic system with fuel at the required flow rates with a pressure rise across the pump of 1500 psi.

Integrator and proportional servo valves have been incorporated to maintain a constant pump pressure rise.

Auxiliary cam plates, which are loaded by rotor springs, hold the piston shoes against the cam plate at all times, assisting the return of the pistons during the suction strokes.

The geometry of the spherical cam plate face and convergent piston axes significantly reduces the side loading applied to the pistons when they are in the extreme retracted position. This design feature also takes advantage of centrifugal force to help retrace the pistons and minimizes the pump volume by reducing the diameter of the valving interface.

Hydraulic pump discharge fuel flows through an integral, full-flow filter, with a differential pressure actuated bypass, which is actuated if the pressure drop through the filter exceeds 20 psi.

The external drive spline is forced-oil-lubricated by the engine oil lubrication system.

(5) Ignition System

The low tension system was chosen because of the ability of the leads and connectors to transmit the exciter discharge voltage at high altitude and temperature conditions without complex pressurization and sealing methods.

This system utilizes a nonradioactive exciter discharge tube, an alternating current as a power source to eliminate the vibrators required on direct current powered systems, and a fusion welded steel exiter box to improve the sealing of the unit.

The spark time duration of a low tension ignition system is shorter than that of a high tension system and does not require the use of the high frequency transformer coil in the discharge circuit. This results in a higher peak power in the first pulse of the spark, which increases the effectiveness of the spark in igniting the fuel air mixture of the burner.

The shunted igniter's ability to fire is virtually unaffected by engine burner pressure or contamination of the electrodes by fuel or carbon type deposits.

The ignition leads which represent a resistance loss in the discharge circuits are designed for the shortest possible length to provide maximum energy at the igniter gap for the ignition of the fuel air mixture.

The ignition system exciters are fuel cooled through the use of a low stress fuel cooling coil to provide separation of fuel from the electrical components.

Redundancy and increased life is provided for the gas generator ignition system by the use of the individual exciter and switch systems.

E. DESIGN RELIABILITY ACTIVITIES

1. Historical Data Bank

Pratt & Whitney Aircraft maintains a service data bank based on over 83 million hours of commercial and military turbine engine experience. This system provides detailed information on all engines currently in operation and a historical record of the reliability of previous engines. The Service Records Group, which is a section of the Service Department, collects, categorizes, and stores failure and success information from Field Service Representative's Reports and Airline and Government data systems. These data provide the foundation for all the Design Reliability Activities. Figure 16 (paragraph G2) illustrates the flow path of service information for the JTF17 Project from the Field Representative, through the Program Management and Service Department, the Design Department and the JTF17 Reliability Data Bank.

Service Engineering records contain data from all Pratt & Whitney Aircraft engines. The data are assimilated into an electronic data processing system and forwarded to the Reliability Groups and Project Management for use in reliability analyses. These data are published by the Service Records Group in the form of summaries, reports and data processing printouts as listed below:

Engine Maintenance Analysis Index
Inflight Discrepancy Index
Premature Engine Removal Index
Engine Removal Index
Commercial Inflight Shutdown Summary
Commercial Premature Engine Removal Summary
Engine Maintenance Analysis Reports

The contents and function of these various publications are discussed in Exhibit A.

2. Design Review

Formal design reviews will be scheduled during the design of the JTF17 engine as a means of enhancing its reliability. During

Phase III Pratt & Whitney Aircraft will continue the basic procedures and design reviews employed for Phase II-C, which are similar to those used on previous development programs.

The Design Reliability Engineer under the direction of the Chief of Reliability performs a continuous review of the JTF17 design for reliability. The procedures employed are a part of the closed loop reliability assurance system shown in figure 4. The system ensures adequate reliability input to the design requirements, provides for approval of all layouts by the Chief of Reliability or his delegate, and assures that reliability requirements will be a part of any redesign following a Phase III development program failure. The prerequisites for design review for reliability are the analysis of service and development test failure data, the reliability apportionment, the Failure Mode and Effect Analysis, the Reliability Check List (a typical page of a reliability checklist is shown in figure 5), and the reliability tradeoff studies. These activities are described in other sections of this plan. The Configuration Management Board has final approval of the design review procedure. The organization and activities of the Board are described in the Configuration Management Plan. Design review consists of the following:

1. The design layout is reviewed by the Design Reliability Engineer for conformance with reliability requirements.
2. The Design Reliability Engineer as directed by the Chief of Reliability approves the layout by signing. If the layout is not approved, a Reliability Engineering Layout Review (RELR) sheet is prepared (figure 6), setting forth the objections and requesting:
   a. Additional analysis or study or a minor change in design (in which case the layout is immediately returned to the designer).
   b. Specific reliability tests which are added to the reliability test requirements following which he approves the layout.
   c. A major change in design which is referred to the Configuration Management Board for review.

3. The Configuration Management Board reviews the RELR, the layout and the design tradeoff studies and:

   a. Requests a new tradeoff study, or
   b. Directs a major change in design, or
   c. Rejects the concerns expressed on the RELR and directs the Chief of Reliability to approve the layout.

4. Following Reliability Layout Approval (or Engineering Change Approval) by the Chief of Reliability or his delegate the layout (or Engineering Change) is approved in accordance with the approval system described in the Configuration Management Plan. The system requires approval from all of the Product Assurance disciplines, the Program Development Manager and the Program Manager.

As described in Volume V, a Formal Design Review Board composed of senior engineers from many Pratt & Whitney Aircraft engine projects is convened periodically to review design concepts and ensure that significant information is exchanged between projects.

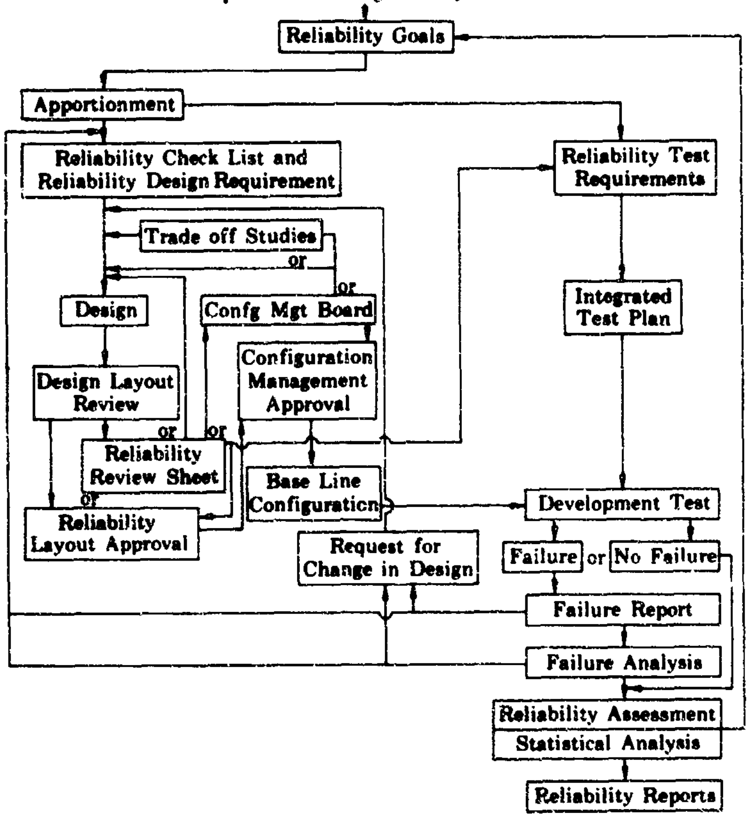


Figure 4. Reliability Flow Chart

FD 17548
FII

SECTION V
FAN, COMPRESSOR AND TURBINE

1. Has adequate radial and axial clearance been provided between rotating and static structures to prevent severe rubbing during steady-state and transient operating conditions, compressor surge and foreign object ingestion?
2. Will blade and vane engagement occur before a stationary member can cut a disk web for large axial rotor deflections?
3. If turbine rotor becomes uncoupled from the compressor, has sufficient axial freedom been provided to ensure turbine blade and vane engagement before some other stationary member could afford a temporary bearing surface to the rotor?
4. Have foolproofing provisions been incorporated to prevent misassembly of turbine vane diaphragms, and all other assemblies?
5. Has adequate provision for static and dynamic balancing been provided? (Where possible, balancing should be accomplished by removal of material, particularly on detail parts.)
6. Has the possibility for rotor unbalance due to shift of components been minimized?
7. Are the number of parts in the radial stackup minimized to reduce excessive eccentricity?
8. Will snap fits be maintained at all operating conditions?
9. Are flexibilities of spacer flanges compatible with growth of mating disks?
10. Has adequate length for snap engagement been provided between disks and spacers for more positive assembly?
11. Has adequate consideration been given to the possibility of blade excitation due to struts or probes upstream or downstream from a particular stage?
12. Do static knife edge seals rub on load-carrying rotor member? Could failure of that rotor part affect rotor integrity?

Figure 5. Typical Page of a Reliability Checklist

FD
FII

RELIABILITY ENGINEERING LAYOUT REVIEW

Layout No.________ Title ______________________________

Designer ________________ Review Date ________ By: ____________

Item | Remarks

Follow Up

Item | Date | Results

PWA 10697D

Figure 6. Reliability Engineering Layout Review

FII

3. Redundancy Analysis

Redundancy may take several forms: overdesign, alternate standby components, or parallel operating components. Redundancy is employed when reliability analysis indicates the required reliability goals cannot be obtained with a single element, component, or subsystem.

The need and level of redundancy required is determined in the following manner:

1. The function of the system and the sequence of operations that must occur for the success of the overall system is established.
2. If the required reliability apportioned to the system cannot be obtained, systems utilizing various types and levels of redundancy, are investigated.
3. The type of redundancy (parallel, series-parallel, parallel-series, overdesign) selected is based on a trade study of safety, reliability, performance, maintainability, weight, space complexity and cost.
4. Development testing of the system may be conducted to substantiate the use of redundant elements.

The electrical ignition system and compressor inlet temperature sensing system are two typical examples of redundancy in the JTF17 design.

Redundant elements are required in the ignition system to provide reliable ignition capability for both the gas generator and duct heater for critical portions of the SST mission. The low tension system selected consists of two fuel cooled exciter packages each containing two independent exciter circuits each of which supply pulsed electrical power for one gas generator igniter and one duct heater igniter. Only one igniter is required to obtain a light. This system results in a lightweight, low temperature operating design that is compatible with the extreme altitude and ambient temperature conditions that will be encountered.

Based on high temperature and high Mach number experience gained from the J58 engine program, redundant elements were considered necessary in the compressor inlet temperature sensing system to ensure the main fuel control receives the required T_{t2} signal in the event of failure of one of the probes. Two helium-filled tube sensors are used to accomplish this task. Since two sensors are used, a signal selector valve is required to determine which pressure signal represents the highest temperature indication. Using the highest temperature signal improves the overall engine reliability by reducing the possibility of engine overtemperature. An indicator is incorporated in the system to provide a means of detecting probe failure.

During the prototype development, flight test, and operational phases, studies to determine the need for redundancy will be continued.

4. Tradeoff Studies

Reliability is one of several requirements in the design of an engine. Additional requirements involve performance, weight, noise, safety, cost, maintainability, value engineering, etc. To properly weigh the relative merits of various approaches to satisfy these requirements, tradeoff studies are made to assure optimization of the design.

The decisions made in tradeoff studies are based on analysis which includes related experience and testing. The analytical methods used are the result of many years and cycles of product design, manufacturer, operational experience, and consequent design improvement.

Each potential configuration is evaluated with respect to its present capability as well as its growth potential. Both development cost and time are considered in the selection of a design to achieve the established requirements and goals for reliability, performance, etc.

During design, most of the parameters are determined analytically. There exist many trades and interactions which have opposing effects within the optimization of an engine configuration and dictate an exceedingly complicated analytical procedure. The use of high speed computers has made it possible to study an unprecedented number of design alternates before making the final selection. The computer programs examine the alternate designs through a series of simulated flight

conditions consisting of the entire range of temperature transients and related stress levels. The more promising design configurations generated as the result of tradeoff studies are verified by test programs. As the design progresses, additional tradeoff studies result in redesigned parts and components.

The following are brief descriptions of tradeoff studies that have resulted in the engine configuration proposed and discussed in detail in Volume III of this proposal.

a. Fan Rotor Configuration

A trussed-hub configuration was selected to provide maximum stiffness with minimum weight. The truss design was selected because:

1. It is lighter than the bolted box disk
2. It has no bolt holes through disks, which eliminates the bolt hole LCF problem
3. It permits removal of the 1st-stage rotor as a separate unit
4. It does not necessitate development of pressure bonding or welding techniques required for a fabricated and bolted design which are beyond the state-of-the-art for commercial engine application.

b. Primary Combustor Configuration

Annular ram-induction combustor was selected because:

1. It reduces the amount of diffusion required, as compared to a static-fed burner
2. It permits a reduction in diffuser length and a reduction in total pressure loss usually inherent in the diffusion process
3. The pressure loading of the scoop modules is much lower than a conventional static pressure drop
4. Ease of removal and replacement of major components
5. It eliminates separate burner cans and associated problems of crossover tubes and clamps
6. It eliminates the long diffuser, the high-loss dump section, the large cross section area, and the high pressure drop required to prevent reverse flow in the front holes of a can annular configuration
7. It provides an even temperature profile to the turbine section
8. Of the effective conductive cooling obtained with high velocity air coupled with the fact that the combustor takes most of its structural load in walls that are not adjacent to the hot gas path, provides a long-life resistance to failure.

c. First Stage Turbine Rotor Configuration

The rotor selected has an integral arm at the bore. This configuration was selected because:

1. It eliminates the need for a separate shaft to secure it to the high-compressor shaft
2. It has better alignment due to a reduction in number of joints

3. It has improved balance capability
4. It has better vibration characteristics
5. It avoids holes in high stress regions
6. It has minimum weight without sacrifice of reliability.

d. Bearing Seal Configuration

The configurations studied were:

1. All labyrinth seals
2. Pressurized-dry face carbon seals
3. Hydrostatic seals.

The hydrostatic system seal was selected because of the following advantages:

1. Extended life, because virtually no wear occurs during normal operation.
2. Minimum heat generation by the seal.
3. Minimum airflow into the compartment and resultant minimum overall heat input into the lubrication and fuel systems.
4. Insignificant air bleed requirements from the engine cycle.
5. Low supply and breather flows reduce the size, number, and congestion of external piping.
6. Oil contamination and oxidation is lessened.
7. The centrifugal deoiler size is reduced and effectiveness increased by low breather flows.
8. Compartments are positively sealed while the engine is stationary.
9. The seals have the ability to function as standard contacting carbon seals in the event of a malfunction or loss in pressure.
10. In the event of hydrostatic seal failure the system has the safety feature advantage of venting oil vapors overboard.

The choice of the unitized concept for the main fuel control was based on a quantitative reliability trade study described in Volume III, Report B, Section III.

5. Reliability Block Diagrams

A reliability block diagram is the first step in the reliability analysis of an engine, subsystem, component and part. The diagrams are made by Design Reliability Engineers and show the logical relation of parts in a component, components in a subsystem and subsystems in the JTF17. These diagrams expedite rapid analysis of assumed failure mode effects and evaluation of redundancy applications. A preliminary reliability block diagram was completed for each JTF17 engine subsystem in November, 1965. An example of these diagrams is shown as figure 7. Each block on the diagram has a numerical identification. This identification is compatible with the Failure Mode and Effect Analysis (FMEA), the mathematical model, and the Development Reliability Group Problem Files to provide rapid traceability of assumed failure modes for each component. As the block diagrams are extended to lower levels, the identification numbers will be extended until there is a number assigned to each failure mode, indicating major section, component and subassembly by its numerical structure.

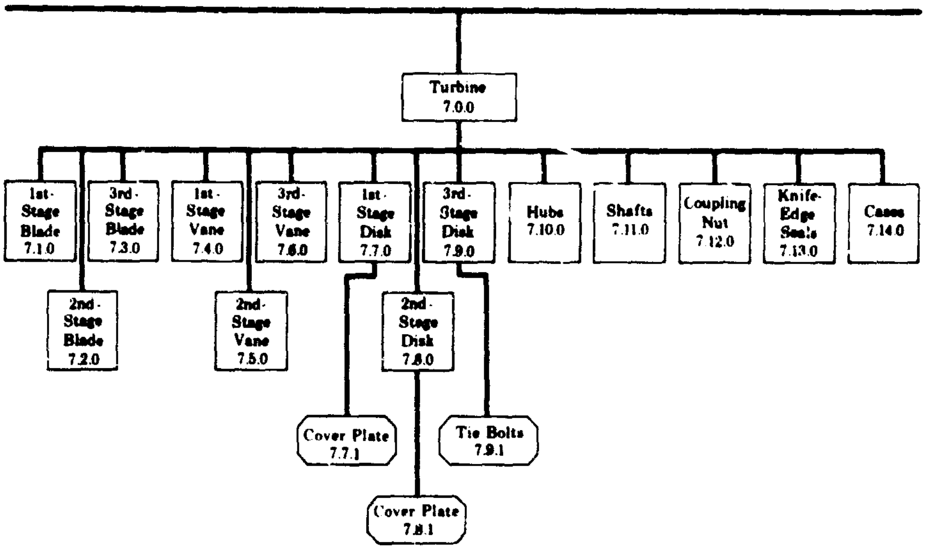


Figure 7. JTF17 Reliability Block Diagram FD 16904 FII

The identification numbers are illustrated in the example shown in Paragraph E.8, Mathematical Model. The reliability block diagrams will continue to be revised to reflect design changes, development experience, later failure rate data from existing engines, redundancy applications, and component derating.

6. Apportionment

Reliability apportionment consists of partitioning or apportioning the overall engine reliability among the engine component sections and then further to lower levels of subassemblies and parts as shown on the block diagrams. The apportionment produces a goal, an objective, for the design of each unit.

These goals focus engineering attention on potential reliability problem areas at the earliest possible time when maximum redesign benefits may be obtained at minimum expense. The apportioned goals are also used with the FMEA studies and the mathematical model to yield critically rankings for components and as a guide in setting up component test programs.

The apportioned JTF17 component reliability goals, obtained by the method described below, are shown as figures 8 through 10.

COMMERCIAL ENGINE FAILURE RATE SUMMARY
IN-FLIGHT SHUTDOWN

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
FRONT MOUNT	0	0	0	0	0	No front mount failures have been experienced by existing engines. JTF17 front mount is a similar design with lower stresses than existing engines.
FAN	Not applicable	0	Not applicable	0	0	Inlet case and inlet guide vane caused one-half of fan failures; neither is required on the JTF17. JTF17 fan blades have double shrouds to limit deflections and double bearing area. Positive blade retention by breech-type lock rings. Stress margins are the same or greater than existing engines.
INTERMEDIATE CASE	0	0.000235	0	0	0.001	JTF17 has more power takeoff requirements, and more severe temperature environment than existing commercial engines. Case construction uses all butt-welded forgings with integral bosses to eliminate boss cracking experienced on the JT3C and JT8D. Thrust load path is better than existing engines to avoid stress concentrations at strut leading and trailing edges.
FAN DUCTING	Not applicable	0	Not applicable	0	0	Similar to JT8D engine fan ducting. Reliability includes an allowance for high temperature distortion.
HIGH COMPRESSOR	0.005476	0.002588	0.001338	0.030887	0.001	The JTF17 has less than one-half the number of compressor stages used in the JT3D and JT4A, one vane row is variable angle. The hotter environment requires better materials than existing engines to maintain stress margins while reducing weight. Disk spacers are integral type to limit cracking of this component as experienced on the JT4A and help promote a lower failure rate.

Figure 8. Commercial Engine Failure Rate Summary: In-Flight Shutdown (Sheet 1 of 5)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
IN-FLIGHT SHUTDOWN

FP 66-100
Volume IV
Report F
Section II

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
PRIMARY COMBUSTOR DIFFUSER	0.004563	0.000941	0	0.007488	0.001	Machined forged rings joined by butt-welds are used to reduce cracking experienced on JT3D. Integrally machined bosses eliminate cracking experienced on the JT8D. More severe temperature gradients than present engines.
PRIMARY COMBUSTOR	0.001825	0.000471	0.000446	0.000936	0.001	The reliability predicted for this component and for the duct heater includes an allowance for the advanced concept of ram induction combustion. Ram induction burner has higher velocity air for cooling to give lower metal temperatures. Transition duct has less circumferential variation in temperature than JT3D or JT4A and is less complex than can burners require. Crossover tubes, a major cause of JT8D difficulties, eliminated by annular design.
TURBINE	0.004563	0.004471	0.008026	0.008424	0.0067	The JTF17 engine has a 500°F higher turbine inlet temperature than the JT3D and JT4A. Air-cooled first and second blades and vanes. Predicted reliability includes allowance for unknowns of high temperature technology required. J58 experience used.
TURBINE EXHAUST	0	0.00047[illegible]	0.000446	0	0.0004	Hotter than JT3D or JT4A exhaust case because of environment. Same stress margins as existing engines. Exhaust case is one piece forging to eliminate weld cracking experienced by existing engines.
REAR MOUNT	0	0	0	0	0	No rear mount failures have been experienced by existing engines. JTF17 rear mount is of similar construction with the same stress margins.

Figure 8. Commercial Engine Failure Rate Summary: In-Flight Shutdown (Sheet 2 of 5)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
IN-FLIGHT SHUTDOWN

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
LUBE AND BREATHER SYSTEM	0.022816	0.019295	0.002676	0.025271	0.01	The JTF17 oil system has fewer oil jets than existing engines due to the reduced number of bearings. The improved design of the JTF17 oil system includes: a pinwheel de-oiler capable of reducing oil loss overboard, tubes to carry oil through struts to minimize effects of strut cracks, filters upstream of oil coolers, and a hot oil tank to reduce pumping requirements and heat rejection.
REVERSER-SUPPRESSOR					0	No direct counterpart on existing engines. JTF17 reverser similar to JT3D with proved JT3D bearings. Larger, lightweight structure will cause lower reliability than JT3D. J58 and TF30 experience used for thermal and acoustic environment effects and aerodynamic design to avoid shock instability interactions. Anticipated failure modes will not cause in-flight shutdown.
ALL BEARING COMPARTMENTS	0.031030	0.009648	0.004905	0.017784	0.005	The JTF17 has 4 rotor bearings vs 7 rotor bearings on existing engines. Troublesome No. 3 and No. 4-1/2 bearings used in existing engines have been eliminated. Thrust bearings in the JTF17 are located in a cool area. Bearing compartments receive cool fan discharge air for pressurization. No duplex bearings are required. All bearings are under-race cooled and flanged.
TOWERSHAFT DRIVES AND INTERNAL GEARING	0.003651	0.002824	0.004013	0.001872	0.0026	The majority of problems experienced on existing engines have been due to misalignment at assembly which has been minimized by double spline coupling on the JTF17. Three towershafts used on the JTF17 as compared to one on existing engines.
EXTERNAL GEARBOXES	0.000913	0.001177	0.001338	0.010300	0.003	The JTF17 gearboxes are similar to JT3D and JT4A. Three small gearboxes on JTF17 vs one large gearbox on existing engines.

Figure 8. Commercial Engine Failure Rate Summary: In-Flight Shutdown (Sheet 3 of 5)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
IN-FLIGHT SHUTDOWN

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
ACTUATORS					0	No direct counterpart on existing commercial engines. J58 experience will be used in the design and application of the JTF17 actuators. No failures have been experienced on the J58; the same type hydraulic actuators will be used at one-half the J58 pressures, and in a cooler environment. Actuators will be replaceable without engine removal.
START BLEED SYSTEM	0	0.001177	Not applicable	0.001872	0	The JTF17 start bleed system has 8 small poppet valves vs the 2 butterfly valves on the JT3C and JT3D. A single poppet can fail without affecting the system. The predicted reliability includes an allowance for the high temperature environment and the manifolding required.
CABIN BLEED SYSTEM	0	0	0	0	0	No cabin bleed system failures reported on existing engines during the year data were received. The JTF17 will use similar construction.
IGNITION SYSTEM	0	0	0	0	0	No ignition system failures reported on existing engines during the year data were received. The JTF17 ignition system will be of similar construction. Can be replaced without removing the engine.
PRIMARY COMBUSTOR FUEL AND CONTROL SYSTEM	0.007301	0.003294	0.00713-	0.021528	0.0025	The JTF17 fuel and control system will employ designs similar to the JT8D and J58 engines. The predicted reliability allows for the system required, the high temperature environment compared to existing engines, and the reduction in detail parts and plumbing resulting from unitized controls.

Figure 8. Commercial Engine Failure Rate Summary: In-Flight Shutdown (Sheet 4 of 5)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
IN-FLIGHT SHUTDOWN

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/ 1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
PRIMARY COMBUSTOR PLUMBING	0.000913	0.000706	0.000892	0.002808	0.0002	JTF17 engine plumbing will be greatly reduced by the unitized controls employed. Integral ferrule tubes as used on the J58 engine should eliminate the failures now being experienced on existing engines.
COMPLETE ENGINE	0.083051	0.047298	0.031214	0.129170	0.0344	These numbers represent the total number of failures causing in-flight shutdown.

Figure 8. Commercial Engine Failure Rate Summary: In-Flight Shutdown (Sheet 5 of 5)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
PREMATURE ENGINE REMOVAL INCLUDING FLYOVERS

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/ 1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
FRONT MOUNT	0	0	0	0	0	No front mount failures have been experienced by existing engines. JTF17 front mount is a similar design with lower stresses than existing engines.
FAN	Not applicable	0.000235	Not applicable	0	0.0001	Inlet case and inlet guide vane caused one-half of fan failures; neither is required on the JTF17. JTF17 blades have double shrouds to limit deflections and double bearing area. Positive blade retention by breech-type lock rings. Stress margins are the same or greater than existing engines.
INTERMEDIATE CASE	0.007301	0.000235	0	0.003744	0.002	JTF17 has more power takeoff requirements, and more severe temperature environment than existing commercial engines. Case construction uses all butt-welded forgings with integral bosses to eliminate boss cracking experienced on the JT3C and JT8D. Thrust load path is better than existing engines to avoid stress concentrations at strut leading and trailing edges.
FAN DUCTING	Not applicable	0.002824	Not applicable	0.001872	0.004	Similar to JT8D engine fan ducting. Reliability includes an allowance for high temperature distortion.
HIGH COMPRESSOR	0.041070	0.017884	0.039684	0.072070	0.02	The JTF17 has less than one-half the number of compressor stages used in the JT3D and JT4A, one vane row is variable angle. The hotter environment requires better materials than existing engines to maintain stress margins while reducing weight. Disk spacers are integral type to limit cracking of this component as experienced on the JT4A and help promote a lower failure rate.

Figure 9. Commercial Engine Failure Rate Summary: Premature Engine Removal Including Flyovers (Sheet 1 of 6)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
PREMATURE ENGINE REMOVAL INCLUDING FLYOVERS

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
PRIMARY COMBUSTOR DIFFUSER	0.019166	0.008471	0.020065	0.053351	0.01	Machined forged rings joined by butt-welds, used to reduce cracking experienced on JT3D; integrally machined bosses to eliminate cracking experienced on the JT8D. More severe temperature gradients than present engines.
PRIMARY COMBUSTOR	0.003651	0.002588	0.000892	0.045863	0.005	The reliability predicted for this component and for the duct heater includes an allowance for the advanced concept of ram induction combustion. Ram induction burner has higher velocity air for cooling to give lower metal temperature. Transition duct has less circumferential variation in temperature than JT3D or JT4A and is less complex than can burners require. Crossover tubes, a major cause of JT8D difficulties, are eliminated by annular design.
TURBINE	0.035594	0.038120	0.049494	0.03275[illegible]	0.05	The JTF17 engine has a 500°F higher turbine inlet temperature than the JT3D and JT4A. Air-cooled first and second blades and vanes. Predicted reliability includes allowance for unknowns of high temperature technology required. J58 experience used.
TURBINE EXHAUST	0.011865	0.004000	0.002230	0.000936	0.004	Hotter than JT3D or JT4A exhaust case because of environment. Same stress margins as existing engines. Exhaust case is a one piece forging to eliminate weld cracking experienced by existing engines.
DUCT DIFFUSER	Use	Main Diffuser			0.02	No counterpart on existing engines. Predicted reliability based on the main diffuser having similar construction.

Figure 9. Commercial Engine Failure Rate Summary: Premature Engine Removal Including Flyovers (Sheet 2 of 6)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
PREMATURE ENGINE REMOVAL INCLUDING FLYOVERS

FP 66-100
Volume IV
Report F
Section II

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
DUCT HEATER	Use Primary Combustor				0.005	No counterpart on existing commercial engines. Predicted reliability based on the main burner having similar construction. Duct heater hot gas temperatures are 20% hotter than the main burner but lower temperature cooling air is available to offset this.
VARIABLE NOZZLE					0.002	No counterpart on existing engines. Predicted reliability based on J58 experience for similar components which had hotter environment.
REAR MOUNT	0	0	0	0	0	No rear mount failures have been experienced by existing engines. JTF17 rear mount is of similar construction with the same stress margins.
LUBE AND BREATHER SYSTEM	0.035593	0.018119	0.010255	0.024335	0.01	The JTF17 oil system has fewer oil jets than existing engines due to the reduced number of bearings. The improved design of the JTF17 oil system includes: a pinwheel de-oiler capable of reducing oil loss overboard, tubes to carry oil through struts to minimize effects of strut cracks, filters upstream of oil coolers, and a hot oil tank to reduce pumping requirements and heat rejection.
REVERSER-SUPPRESSOR		0.030706			0.007	No direct counterpart on existing engines. JTF17 reverser similar to JT3D with proved JT3D bearings. Larger, lightweight structure will cause lower reliability than JT3D. J58 and TF30 experience used for thermal and acoustic environment effects and aerodynamic design to avoid shock instability interactions.

Figure 9. Commercial Engine Failure Rate Summary: Premature Engine Removal Including Flyovers (Sheet 3 of 6)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
PREMATURE ENGINE REMOVAL INCLUDING FLYOVERS

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
ALL BEARING COMPARTMENTS	0.123209	0.034355	0.039684	0.048671	0.02	The JTF17 has 4 rotor bearings vs 7 rotor bearings on existing engines. Troublesome No. 3 and No. 4-1/2 bearings used in existing engines have been eliminated. Thrust bearings in the JTF17 are located in a cool area. Bearing compartments receive cool fan discharge air for pressurization. No duplex bearings are required. All bearings are under-race cooled and flanged.
TOWERSHAFT DRIVES AND INTERNAL GEARING	0.014403	0.005883	0.002675	0.005616	0.01	The majority of problems experienced on existing engines have been due to misalignment at assembly which has been minimized by double spline coupling on the JTF17. Three towershafts used on the JTF17 as compared to one on existing engines.
EXTERNAL GEARBOXES	0.017340	0.015531	0.023632	0.098278	0.03	The JTF17 gearboxes are similar to JT3D and JT4A. Three small gearboxes on JTF17 vs one large gearbox on existing engines.
ACTUATORS					0	No direct counterpart on existing commercial engines. J58 experience will be used in the design and application of the JTF17 actuators. No failures have been experienced on the J58; the same type hydraulic actuators will be used at one-half the J58 pressures, and in a cooler environment. Actuators will be replaceable without engine removal.
START BLEED SYSTEM	0.005475	0.000706	Not applicable	0.005616	0.0006	The JTF17 start bleed system has 8 small poppet valves vs the 2 butterfly valves on the JT3C and JT3D. A single poppet can fail without affecting the system. The predicted reliability includes an allowance for the high temperature environment and the manifolding required.

Figure 9. Commercial Engine Failure Rate Summary: Premature Engine Removal Including Flyovers (Sheet 4 of 6)

FII

COMMERCIAL ENGINE FAILURE RATE SUMMARY
PREMATURE ENGINE REMOVAL INCLUDING FLYOVERS

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/ 1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
CABIN BLEED SYSTEM	0	0	0	0	0	No cabin bleed system failures reported on existing engines during the year data were received. The JTF17 will use similar construction.
IGNITION SYSTEM	0	0	0	0	0	No ignition system failures reported on existing engines during the year data were received. The JTF17 ignition system will be of similar construction. Can be replaced without removing the engine.
FUEL AND CONTROL SYSTEM	0.004563	0.003294	0.024524	0.006552	0.010	The JTF17 fuel and control system will employ designs similar to the JT8D and J58 engines. The predicted reliability allows for the two systems required, the high temperature environment compared to existing engines, and the reduction in detail parts and plumbing resulting from unitized controls.
ENGINE PLUMBING	0.005475	0.002118	0.000446	0.025271	0.0003	JTF17 engine plumbing will be greatly reduced by the unitized controls employed. Integral ferrule tubes as used on the J58 engine should eliminate the failures now being experienced on existing engines.
UNEXPLAINED	0.051109	0.034826	0.025416	0.064583	Not applicable	This entry in existing engine data consists of failures that have not yet been traced to any component. This number is a function of airline overhaul shop work load and in many cases no reason for the engine removal is found. Not included in JTF17 reliability prediction.

Figure 9. Commercial Engine Failure Rate Summary: Premature Engine Removal Including Flyovers (Sheet 5 of 6)

COMMERCIAL ENGINE FAILURE RATE SUMMARY
PREMATURE ENGINE REMOVAL INCLUDING FLYOVERS

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
COMPLETE ENGINE	0.324905	0.155069	0.213581	0.494934	0.2000	These numbers represent the total number of failures experienced in the number of hours logged for the complete engin excluding the incidents in the paragraph entitled "UNEXPLAINED."

Figure 9. Commercial Engine Failure Rate Summary: Premature Engine Removal Including Flyovers (Sheet 6 of 6)

FII

COMMERCIAL ENGINE FAILURE RATE SUMMARY
INABILITY TO OBTAIN SELECTED AUGMENTOR THRUST

FP 66-100
Volume IV
Report F
Section II

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/ 1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
DUCT DIFFUSER	Use primary combustor diffuser				0.001	No counterpart on existing engines. Predicted reliability based on the main diffuser having similar construction.
DUCT HEATER	Use primary combustor				0.001	No counterpart on existing commercial engines. Predicted reliability based on the main burner having similar construction. Duct heater hot gas temperatures are 20% hotter than the main burner but lower temperature cooling air is available to offset this.
VARIABLE NOZZLE					0.001	No counterpart on existing engines. Predicted reliability based on J58 experience for similar components in hotter environment.
AUGMENTOR FUEL AND CONTROL SYSTEM	Use primary fuel and control system				0.0025	No counterpart on existing engines. Predicted reliability based on the primary fuel and control system having similar construction.
AUGMENTOR PLUMBING	Use primary fuel and control system plumbing				0.0001	No counterpart on existing engines. Predicted reliability based on the primary fuel and control system plumbing having similar construction.

Figure 10. Commercial Engine Failure Rate Summary: Inability to Obtain Selected Augmentor Thrust (Sheet 1 of 2)

FP 66-100
Volume IV
Report F
Section II

COMMERCIAL ENGINE FAILURE RATE SUMMARY
INABILITY TO OBTAIN SELECTED AUGMENTOR THRUST

ENGINE SECTION	ACTUAL ENGINE FAILURES/1000 HOURS				APPORTIONED MATURE JTF17 FAILURES/1000 HOURS	COMMENTS
	JT3C	JT3D	JT4A	JT8D		
AUGMENTOR					0.0056	This number represents the total number of failures/1000 hours resulting in the inability to obtain selected augmentor thrust.

Figure 10. Commercial Engine Failure Rate Summary: Inability to Obtain Selected Augmentor Thrust (Sheet 2 of 2)

FII

The apportionments are based on the service data bank, described in Paragraph E.1 of this plan. The sample of failure data used was taken from the JT3-C and JT4-A commercial turbojets, the JT3-D and JT8-D commercial turbofans, and the J57 and J58 military turbojets and consisted of more than eight and one-half million hours during the twelve month interval selected as a base for the apportionment. Engine data was divided into subsystems such as compressor, turbine, oil, control, etc. The JT3-D data was most heavily weighted as this engine is a mature turbofan. The JT4-A data was ranked next in the weighting as this engine is a mature turbojet. The JT3-C is entering the wear out phase of service and the JT8-D has not yet reached maturity. The military data includes the J58 turbojet, designed and developed at the FRDC, an engine that operates in a more severe environment than the JTF17. J58 data was used in predicting SST environmental effects. Separate analyses were made for failures causing in flight shutdowns, premature engine removals and inability to obtain selected augmentor thrust.

In using the accumulated service data to establish JTF17 component reliability goals special consideration was given to eliminating the failure modes that exist in the current engines. In this process all factors bearing on the reliability were considered such as detail design features, operational environments, internal stresses, stress concentrations, factors of safety, degree of complexity and risk, number of parts, and human factors or maintenance procedures.

The mature reliability goals shown in figures 8 through 10 were apportioned early in the JTF17 design phase. This early goal determination promotes early goal attainment by focusing attention to areas where estimated reliability and apportioned reliability are not compatible while the design is in its most fluid state. As the JTF17 design progresses, some subsystem goals may have to be revised to reflect changes in engine requirements, tradeoff study results, technical breakthroughs and development test experience.

The reliability apportionments will be revised as the engine accumulates service time to focus early attention on commercial problems. The revision dates currently planned are shown on the Reliability Milestone Chart, figure 17 (paragraph H).

7. Failure Mode and Effect Analysis

The FMEA is the foundation of design reliability analysis. It consists of an analysis of all potential failures and/or malfunctions of all of the components and parts of the engine considering their function and their effects on mission capability. These analyses are performed at times consistent with program design phases. In the early design phase, the analysis considers the consequences of failure at the highest system or assembly level. In later phases, the analyses become progressively more detailed and ultimately will be conducted at the subassembly and part level.

A First Edition of the FMEA was completed in November, 1965.

A Second Edition of the FMEA was completed on 15 July 1966 and was published as PWA Report FTDM 214. A sample sheet of the Second Edition is shown in figure 11. A Third Edition will be completed in November 1966 and will include more detail with the addition of Sheet II of the FMEA format, figure 11.

Sheet 1

JTF17 FAILURE MODE & EFFECT ANALYSIS

No. 24 of 37

Item	Function	Failure Mode	Failure Effect on Subsystem	Method of Detection	Failure Effect on Engine	Failure Effect on Aircraft	Crew Action Require
14 REVERSER-SUPPRESSOR 14.0.0							
Mount Ring 14.1.0	Part of duct heater nozzle support case and provides support points for bolting R/S to engine.	Deflection.	Tertiary door binding or jamming due to deformation of R/S.	Reduced performance. Ground inspection. Also see Section 14.3.0	Reduced performance. See Section 14.3.0.	Ground inspection may require parts replacement.	Adjust thrust, clo: fuel management. Request inspection. Also see Section 14.3.0.
Main Structure 14.2.0	Listed below.						
Structural Members 14.2.1	Structural framework for transmitting loads and holding shape of R/S.	Loose or sheared rivet, failed weld or fractured parent metal.	Overstress of adjacent parts and progressive failures until operation of clamshell or tertiary air doors is impaired by sag or deformation.	Impaired operation, ground inspection.	None until operation of moving parts is impaired.	Removal of reverser-suppressor for repair.	If R/S operation is impaired, reduce thrust and do not use reverser.
Inner Skin 14.2.2	Form smooth air flow path and shield structure from hot gases.	Tear loose, crack or burn-through.	Disrupt air stream causing reduced performance, weaken structure, expose structure to high temperature gases.	Reduced cruise thrust, ground inspection.	None if cracked, reduced performance if loose or burned through.	Removal of reverser-suppressor for repair.	Adjust thrust. Close fuel management. Request inspection.
Outer Skin 14.2.3	Form smooth air flow path and structural rigidity.	Tear loose or crack.	Disrupt air stream causing reduced performance and weaken structure.	Reduced cruise thrust.	None if cracked, reduced performance if loose.	Possible removal of reverser-suppressor for repair.	Adjust thrust. Close fuel management. Request inspection.
Mount Lugs 14.2.4	Provides attach points for bolting R/S struts to engine.	Sheared rivets or fracture of lug.	None, more than 2 adjacent lugs must fail to propogate effect.	Ground inspection for excessive gap at mount face.	None	Parts replacement at overhaul or remove reverser-suppressor for repair.	None
Tertiary Air Door 14.3.0	1. Admit tertiary air during subsonic operation.	Jammed closed	Reduced subsonic performance and overstress of parts from excessive OD to ID ΔP.	Thrust reduction, ground inspection.	Reduced subsonic performance	Inspect and repair.	Adjust thrust. Request inspection
	2. Permit exit of exhaust gases during reverse.	Jammed closed	Clamshells will be locked out of reverse position.	Loss of reverse capability, ground inspection.	Loss of reverse thrust.	Inspect and repair.	Adjust for lack of reverse thrust, request inspection
	3. Prevent loss of exhaust gases during supersonic operation.	Jammed open.	Gas leakage. Clamshells will be locked out of supersonic position.	Reduced thrust at supersonic condition, ground inspection.	Reduced supersonic performance.	Inspect and repair.	Adjust thrust. Close fuel management. Request inspection.
Door-Panels (Honeycomb) 14.3.1	Structural support and flow path contour.	Separation of skin from core or fracture at attach points.	None, unless extreme in which case air flow could be disrupted with minor loss in performance.	Ground inspection.	None	Inspect and repair door panel.	None

Analyzed by: Design Date 3-64 Reliability Date July 1964 Project Date

Figure 11. JTF17 Failure Mode and Effect Analysis (Sheet 1 of 2)

FII

Sheet 2

JTF17 FAILURE MODE & EFFECT ANALYSIS

No. ___ of ___

Item	Function	Failure Mode	Hazard Classification				Design Philosophy To Preclude Failure	Design Philosophy To Reduce Hazard
			I	II	III	IV		

Analyzed by:

Figure 11. JTF17 Failure Mode and Effect Analysis (Sheet 2 of 2)

A detailed FMEA on the main fuel control is described and illustrated in Volume III, Report B, Section III. This study was conducted with the fuel control vendors.

The objectives of the FMEA are to:

1. Provide the design activity with a method of recognizing the concept of inherent reliability, i.e., that reliability is limited by design and that effort must be concentrated early in the design phase and carried through to the final design stages.
2. Ensure that design effort is directed toward developing a highly reliable product capable of operating without failure incident for long periods of time consistent with total mission requirements.
3. Provide an additional method to ensure that the designer has considered all conceivable failure modes reflecting field and development experience and their effects on operational success of the system.
4. Uncover critical reliability areas and direct appropriate engineering attention to them early in the design stage.
5. Ensure that reliability and the related maintainability and safety requirements are implemented in the design and are retained during all phases of manufacturing, testing, handling, and application.
6. Provide a single source of information which reflects the latest design concepts and design philosophy.
7. Ensure that effort is directed toward elimination of potential sources of human induced errors throughout the design and production of the system or end item.
8. Provide the Safety Engineer with the information necessary to complete a safety analysis of all failure modes.

The FMEA is an engineering design parameter in the same sense that other product characteristics are design parameters. Accordingly, the procedures used for accomplishing the FMEA parallel those used in arriving at other part characteristics of parts or materials and from stresses anticipated in their application. The FMEA procedures are described in Exhibit B.

The FMEA will continue to be updated every six months during Phase III. The schedule is shown on the Milestone Chart (figure 17, paragraph H).

8. Mathematical Model

The JTF17 Mathematical Model will be used to establish the criticality of JTF17 failure modes. These failure modes will be ranked with respect to at least four mission failure effects: premature engine removal, inflight shutdown of the engine, loss of augmentor thrust, and unsafe condition. The mathematical model will be based on the FMEA, the block diagrams and the apportionment of reliability. In addition to the criticality ranking, the model will aid in the evaluation of the effects of design and development decisions by providing the basis for design reliability tradeoff studies.

A criticality ranking of failure modes (figure 12) will be produced for each mission effect, and for each of seven mission segments: start and taxi, takeoff, climb, cruise, descent, landing, and the overall mission. These criticality rankings will be described by the matrix of the probabilities of each mission effect occurring.

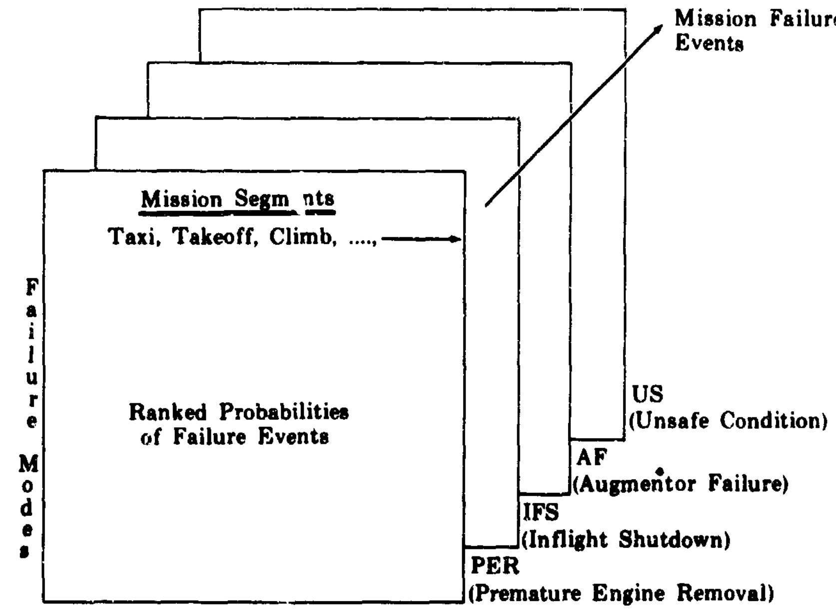


Figure 12. Criticality Ranking of Failure Modes FD 17549 FII

Each probability element in the matrix describes the probability that the indicated failure mode will produce the failure event in the corresponding mission segment.

This may be illustrated by the Venn diagram in figure 13. The area within circle A represents the probability that failure mode A occurs. The exterior area represents the probability that it does not occur. The area within circle B represents the probability that the failure event will occur due to the failure mode A.

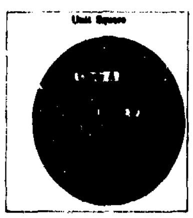


Figure 13. Venn Diagram FD 17550 FII

The occurrence of the failure mode and the occurrence of the failure event are statistically dependent events. The absolute probability of the failure event occurring may be outlined from the general product rule.

$$P(B) = P\,(\underbrace{B \mid A}_{\text{Given}}) \times P\,(A)$$

The probability of the failure event occurring due to this failure mode is e⁻⁻al to the product of the conditional probability of the failure event, given that the failure mode has occurred, times the probability of the failure mode occurring.

The total probability of the failure event occurring is obtained as the sum of the probabilities for all failure modes.

$$P(B) = \sum_{\substack{\text{all failure} \\ \text{modes, } A_i}} P(B \mid A_i)\ P(A_i)$$

For simplicity, the first edition of the mathematical model will not partition the mission into segments. In later editions the mission will be divided up into mission segments: start and taxi, takeoff, climb, cruise, descent, land. Within each mission segment the criticality ranking of failure modes for each of the four failure events will be determined from the mathematical model. At this stage of the development of the model the input structure will consist of two large matrices. The matrix of conditional probabilities will have three dimensions: failure mode, failure event and mission segment. The matrix of probabilities of the failure mode occurring will have two dimensions: failure mode and mission segment.

The mathematical structure of the model is designed to allow for rapid response to redesigns and special reliability studies. The matrix of failure mode probabilities will employ relative rather than absolute frequencies. Initially a scale of frequently, rarely, and never will be employed. The ratio of frequent to rare events will be taken as 10:1. The conditional probabilities will also employ a simple scale. Initially, a scale of certain (1.0), probable (0.80), improbable (0.20) and never (0.0) will be used. These simple approximations will be refined in later editions. The mathematical model will determine the probabilities of the failure events for each failure mode from the relative frequencies, conditioned probabilities and the apportionment. Therefore, changes to the reliability apportionment will not obsolete the model.

To illustrate the concept of the JTF17 mathematical model an example is included as Exhibit C.

The model will have options tc allow use of probability equations and component mathematical models as subroutines in substitution for the failure mode frequencies. This option is particularly helpful for components with redundant elements in parallel and parallel-series arrangements.

Later editions of the mathematical model may include additional events such as engine induced inlet failures, departure and turnaround delays, and failures that may ba corrected by replacement of a component without engine removal.

The mathematical model is the last step in the evolutionary cycle of reliability analysis consisting of the reliability block diagrams, the FMEA, the reliability apportionment and finally, the mathematical model. The timing of the cycle is indicated on the Milestone Chart, figure 17 (paragraph H).

F. DEVELOPMENT RELIABILITY ACTIVITIES

Development reliability activities consist of the collection and processing of development test reliability data, the application of statistical reliability methods to the development program, the correlation of reliability data with reliability goals and the preparation of reliability reports. There are three data processing systems: failure data, critical parts history and test reports. The Development Reliability Group is responsible for all these activities.

1. Failure Data

The Failure-Malfunction Bank was established to provide for development test failure data collection and processing, and to assure feedback of failure information to Design, Project and Reliability Engineers. Computer summaries of failures are available throughout the Engineering Department by component, by part number, and by failure type. These summaries are prerequisite to reliability analysis such as determining failure distributions, failure mode and effect analysis and reliability assessment. Failure summaries are included in each Bimonthly and Semiannual Reliability Report.

There are two basic failure data documents: the Failure Malfunction Report and the Failure Analysis Report. Failure Malfunction Reports are initiated by the Experimental Engineers assigned to each experimental engine, component or rig whenever a failure occurs. The Failure Analysis Report is originated by the cognizant Assistant Project Engineer when he completes the failure analysis.

The actual analysis may be done by the Materials Development Laboratory, the Design Department, Experimental Engineering, Facilities, or the Performance Group as directed by the Assistant Project Engineer.

The detailed processing and distribution of the failure data is described in Exhibit D.

Summaries of failure data by component, and by test will be provided in the Bimonthly Reliability reports. In addition, Semiannual Reports will contain a summary of test failures that may be related to dispatch and turnaround delays and component replacement without engine removal.

2. Critical Parts History

The JTF17 parts history system is designed to maintain a record of test exposure for each critical part. The record shows the identity of the engines or rigs in which the part has been installed and the time span of the installation. The accumulated time or cycles that the part has been run is maintained and updated as the tests are completed. This system provides a life or test history of each critical part installed on all experimental engines, components and rigs.

The life histories are used to describe the mortality distributions of critical parts. Surveys of the Parts History Data Bank are automated and are used to provide test data for Weibull analysis, for

failure rate estimates and for verification of the Failure Mode and Effect Analysis. Surveys may be obtained by part number, part name, engine section, and failure type.

A detailed description of the Critical Parts System is contained in Exhibit E.

3. Test Reports

Before each engine is started in the test area, the responsible Experimental Engineer files a Pretest Report with the Development Reliability Group. The report contains a summary of the test program and test objectives, and components that are significantly different from standard components (excessive repairs, new design not tested previously, overage, out-of-tolerance, etc.). As the test program progresses and the information on the Pretest Report becomes outdated, modified reports are submitted.

A Post Test Report is filed at the end of the test. It contains a summary of significant events, test objectives not completed and may reference Failure Reports submitted. Performance histories are maintained by the Performance Group on every engine test and are available to the Development Reliability Group. The Test Reports, Failure Reports, Parts History and Performance Histories form the basis of reliability assessment.

4. Reliability Problem Files

To ensure reliability control, all reliability failure data, parts history data, and test reports are collected and organized in Reliability Problem Files. The files are serialized by the appropriate failure mode index numbers used on the FMEA. The status of open files will be summarized in the Bimonthly and Semiannual Reliability Reports. A Reliability Problem File is closed when sufficient engine data exists to conclude that the corrective action taken or the redesign has corrected the problem. At least six months of successful test experience should exist before a file is closed. The objective of the Reliability Problem Files is to ensure that effective correction action is taken and to provide a systematic assembly of all pertinent information on each reliability problem.

5. Reliability Assessment

The JTF17 Reliability Assessment System is designed to indicate reliability growth during the development program. The basis for the assessment will be three parameters: Test Stand Premature Engine Removal (TSPER), Test Stand Engine Shutdown (TSES), and Test Stand Augmentor Failure (TSAF). These parameters are directly analogous to the mission parameters but are defined in test stand terms that are more meaningful for gaging development progress. Test Stand Premature Engine Removal is defined as the event that the engine was removed from the test stand because of an engine failure before the test program was completed. Test Stand Engine Shutdown is the event that the engine was shutdown while a test was in progress due to an engine failure. Test

Stand Augmentor Failure was the event that the test program requirements for augmented thrust could not be met ue to engine failure.

The development reliability assessment parameters are a gage of the mission parameters in a relative rather than absolute sense. There are several reasons why it is impossible to make quantitative estimates of the mission parameters from development test data.

a. Sample Size

During the development program there should be a rapid growth of reliability which leads to the concept of a moving average as a point estimate of progress. The sample size of the moving average will necessarily be less than the total development program and in any event it will be several orders of magnitude smaller than that required to make inferences at the mission reliability level. For example, the mean time between inflight shutdown of 25,000 hours is the equivalent of reliability of 0.99996 for a 1-hour mission. A reliability sample of at least 100,000 hours of engine operation is required to make meaningful inferences at this reliability level. The largest sample size for a moving average during development testing would be on the order of 1000 hours of engine operation.

b. Accelerated Testing

The development program includes overstress testing to force potential failure modes in order that effective corrective action can be quickly developed. It requires that a large proportion of the test program be devoted to accelerated testing in both time and environment. To date, quantitative transformations of accelerated testing failures data to the design (nonaccelerated) environment have not been possible and therefore, the bulk of accelerated data must be excluded from reliability assessment. These exclusions result in a further reduction in reliability sample sizes.

c. Nonhomogenous Engines

The evolutionary nature of the development program results in a constantly changing configuration; there are alternate approaches tested to correct weak links, to enhance durability, to improve performance, to reduce cost and weight, and to evaluate fabrication methods and material. The experimental engines are mixtures of new, old, repaired, standard and experimental parts. Each and every engine will be different. Thus, the population sampled (the sample spare) is grossly nonhomogenous.

The general philosophy for the reliability assessment ground rules will be that failures caused by the engine are chargeable to the engine; failures caused by facilities, instrumentation, experimental, old age, or repaired parts, and test stand operator errors will be excluded. The basis for reliability classification will be the documentation that existed prior to the test. In all cases where there is reasonable doubt as to the cause of the failure, the engine will be charged with the failure. The concept that failures may be excluded by making a design change will not be used as it is clearly an optimistic procedure

and tends to bias the reliability estimates toward higher than true levels. The detailed ground rules for reliability assessment will be published as a Pratt & Whitney Aircraft report early in 1967, as shown on the Milestone Chart (figure 17, paragraph H). This report will describe the procedures, philosophy and rules for classifying failures, successes and test exclusions. The document will be coordinated with both the Federal Aviation Agency and the airframe manufacturer.

The Chief of Reliability has final responsibility for all reliability classifications. Reliability assessments with all relevant information, both included and excluded data, will be published in the Bimonthly and Semiannual Reliability Reports.

For each parameter, two estimates will be provided:

1. The maximum likelihood, best, unbiased point estimate
2. A lower 90% confidence bound for an interval estimate bounded above by 1.0

6. Statistical Engineering

The Reliability groups receive statistical research support from the Statistics Group. The objectives of the Statistics Group are to (1) provide statistical consulting service to the Engineering Department, (2) to provide solutions to complex statistical problems, and (3) to standardize statistical methods throughout the Florida Research and Development Center. The majority of the group activities are related to research in statistical reliability, planning and designing experimental test programs, recommending instrumentation configurations and calibration methods for improving the precision and accuracy of data, and analyzing experimental data.

The Statistics Group has published three Pratt & Whitney Aircraft reports on statistical research problems associated with the JTF17 engine during Phase II-C. These reports are listed below:

1. FR-1896 "A Novel Application of Least Squares to Improve Precision"
2. FR-1897 "Optimum Dead Zone"
3. FR-1993 "The Use of Partial Derivatives in Variation Analysis"

G. FLIGHT TEST AND SERVICE RELIABILITY ACTIVITIES

All of the reliability activities described in this plan will be continued through flight test and into the service phase of the supersonic transport program. Early in this period production acceptance test data will substantially increase the amount of valid ground test reliability data available. Later, flight data will gradually replace ground test data as the basic source of information for reliability analysis and statistical inference. The periodic reliability reports will summarize both ground test and flight test data. Design reliability activities will include updating of the FMEA, reliability apportionment, and the mathematical model. However, the period of updating will gradually be increased. Numerical reliability assessment for the mission parameters, inflight shutdown, augmentor failure and premature engine removal will be included in the periodic reports. The projected reliability growth in this period is shown on figures 14 and 15.

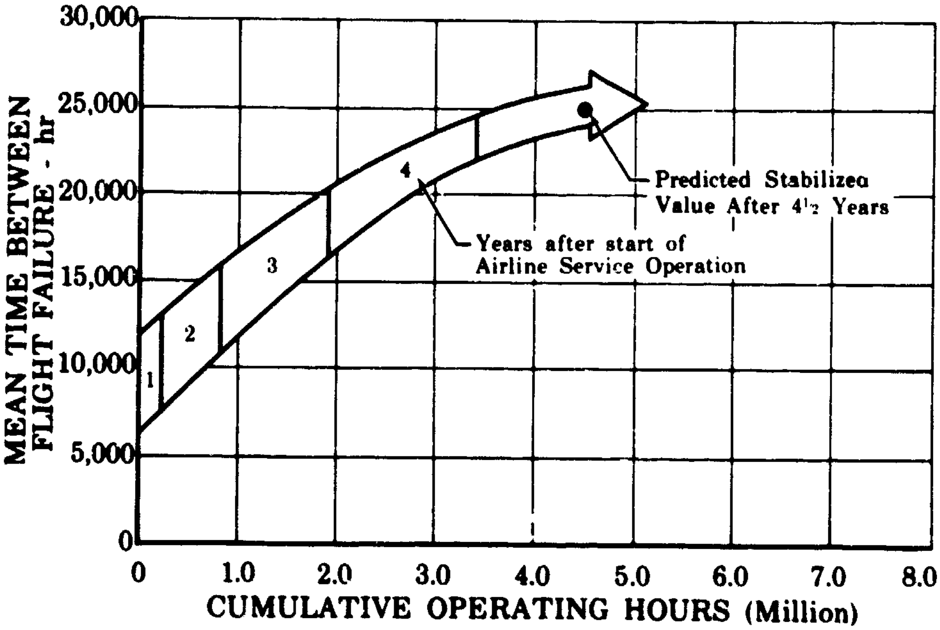


Figure 14. JTF17 Estimated Growth of Mean Time Between Flight Failures (In-Flight Including Augmentor) FD 17547 FII

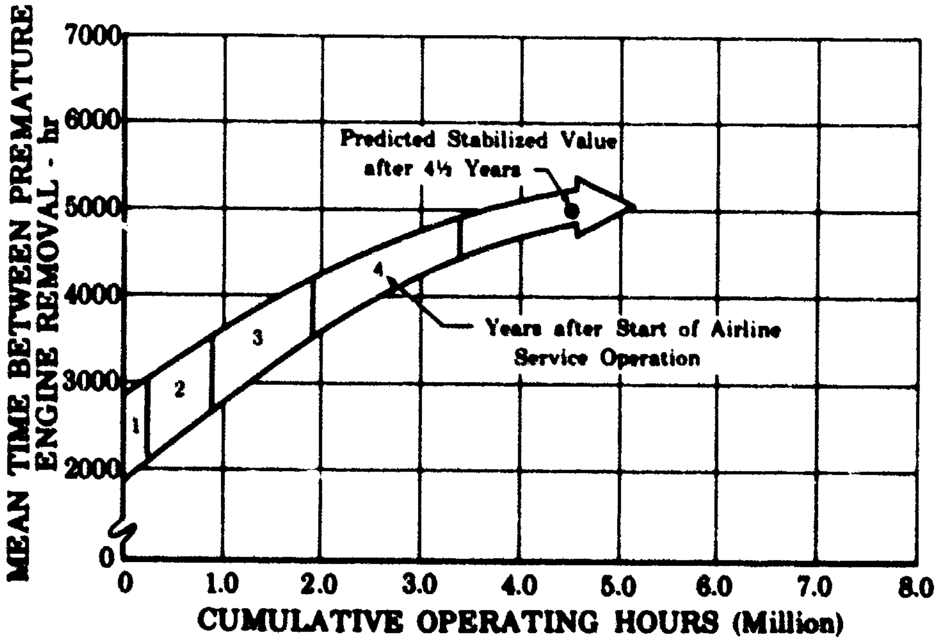


Figure 15. JTF17 Estimated Growth of Mean Time Between Premature Engine Removals Including Flyovers FD 17546 FII

1. Acceptance Testing

Production test is an integral part of the overall reliability assurance program. Surveillance and run-in tests are conducted on selected parts or subassemblies prior to final assembly. New engines are fully assembled and run through test simulating various operating conditions. The purpose of these tests is to catch infant mortality failures from errors, defective parts and improper assembly. Each engine must also meet specified thrust and specific fuel consumption ratings during these tests.

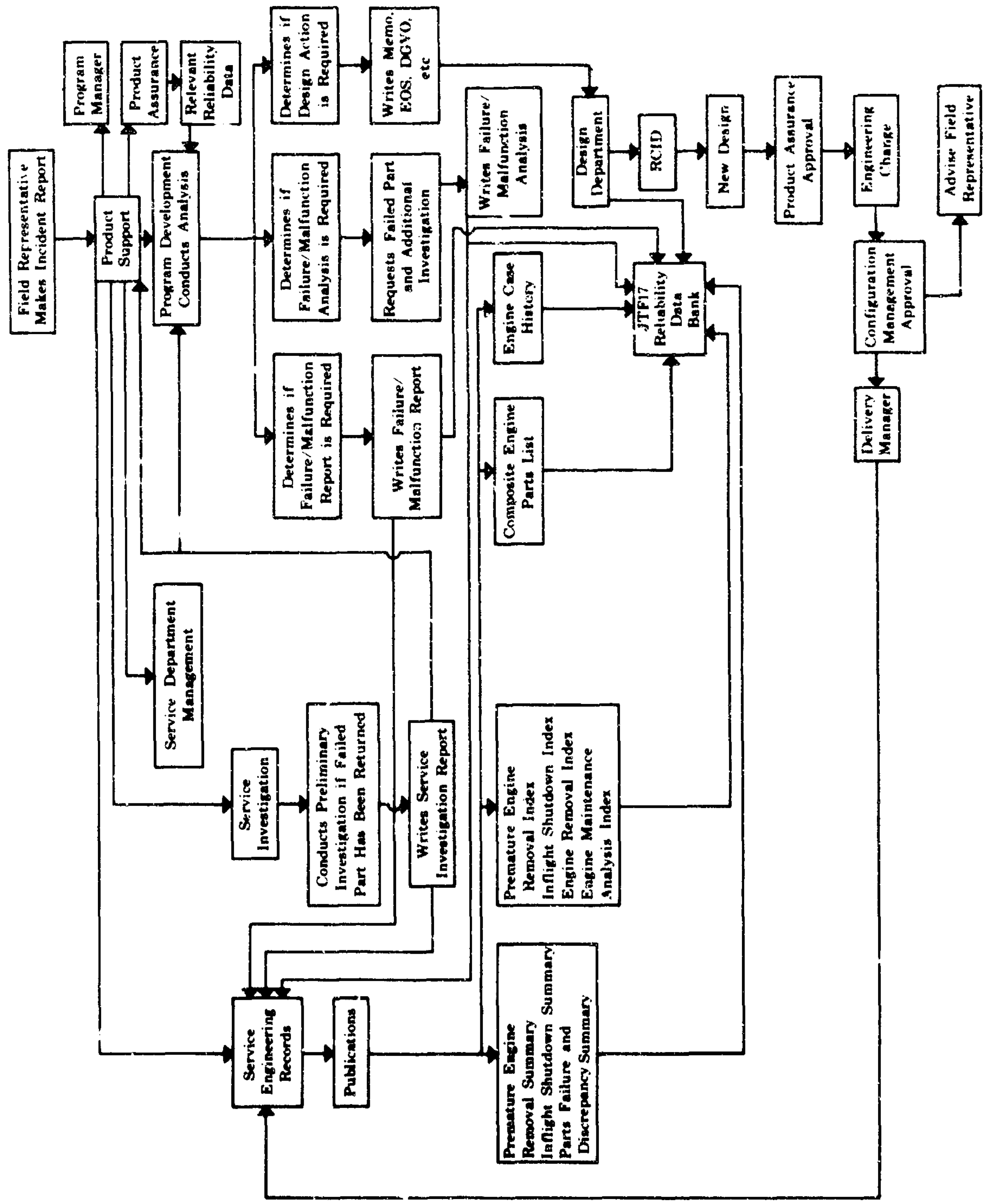
After completion of the initial acceptance test each engine is disassembled and inspected. If no discrepancies are found at this time the engine is rebuilt and a final acceptance run conducted. If the engine still performs to specification and no discrepancies are found, it is packaged for shipment.

The acceptance test data will be used by the Development Reliability Group as an additional source ground test data for numerical reliability assessment. Production acceptance failure data will be summarized in the periodic reliability reports in the same manner as development test data.

2. Flight Data

Failures occurring in service and flight test engines will be reported through the Pratt & Whitney Aircraft Service Representatives to the Product Support Group. The Product Support Group is described in Section VI. The flow of service information is illustrated in figure 16. Problems requiring immediate action will be handled by Service Engineering under the Product Support Manager. Investigation and corrective action will be initiated as though the failure occurred in a development test. When required, JTF17 Program personnel will be dispatched for more detailed, on-the-spot analysis. If necessary the failed parts will be delivered to Pratt & Whitney Aircraft for more thorough analysis. The Project Development Group will analyze failed parts received from the field in cooperation with the Product Support and the Product Assurance Groups. The Reliability Groups provide relevant reliability data and analysis. Corrective action will be initiated by the Project Engineering Group under the Development Manager. When substantiated, the action may take the form of an Engineering Change, Service Bulletin, or an updating of the Service Manual.

The Service Department data bank and publications are described in Exhibit A. Human engineering, maintainability and safety during the flight test and service phases are treated in their respective plans in this proposal. The Product Support and Delivery Groups activities are also closely related to reliability and are described in Section VI.



FD 17520

Figure 16. JTF17 Service Data Information Flow Path

H. RELIABILITY REPORTING AND MILESTONES

All of the reliability control reports and summaries described herein will be available to the Federal Aviation Agency, the airframe manufacturer and the airlines. The Reliability Report Matrix, table 2, describes the distribution of the information; the Reliability Milestone Chart, figure 17, shows the time schedule of reliability reports, tasks and activities.

Table 2. Reliability Report Matrix

Report	FAA (Distribution)	Airframe (Distribution)	Airlines (Distribution)
Reliability Block Diagrams	D	R	R
Failure Mode and Effect Analysis	D	D	R
Airframe Mathematical Model Input	R	D	R
Bimonthly Reliability Report	D	D	R
Semiannual Reliability Report	D	D	R
Statistical Research Reports	R	R	R

D - Routine Distribution
R - If Requested

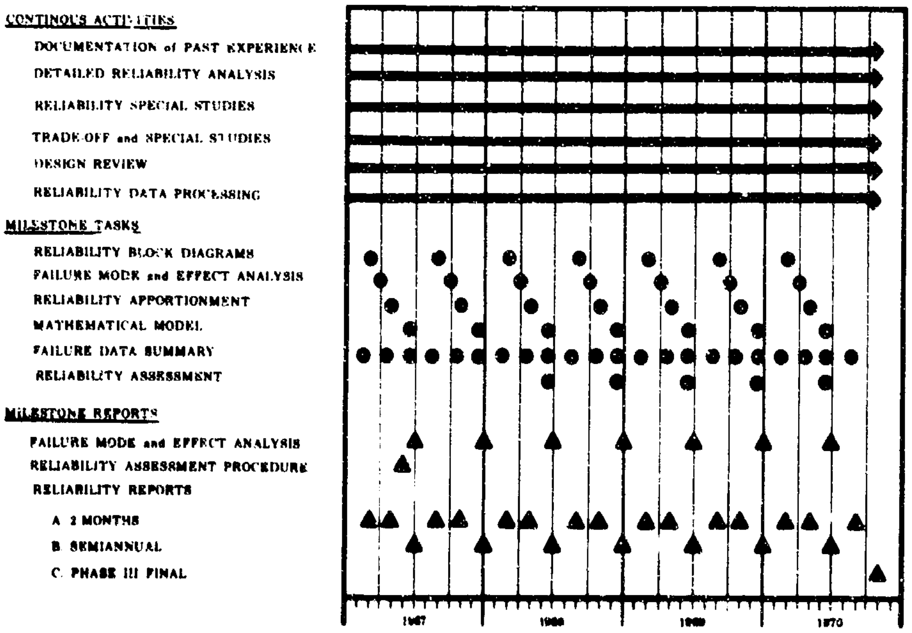


Figure 17. Reliability Milestone Chart

FII

The Bimonthly Reliability Reports will contain the following information:

1. Revised Reliability Block Diagrams
2. Updated Failure Mode and Effect Analyses
3. Revised Reliability Apportionment
4. Summaries of Mathematical Model Computer Studies
5. Special Studies

6. A Failure Data Summary by Component Section
7. A Status Summary on Open Reliability Problem Files

The Semiannual Reliability Report will contain the above information plus:

1. Numerical Reliability Estimates starting in July 1969
2. All data required to substantiate the numerical estimates including a chronological listing of every engine test within the period of the moving average, both included and excluded from reliability classification.
3. A summary of failure data related to aircraft dispatch and turnaround delays.
4. If revised, a copy of the Reliability Program Plan.

The Reliability Assessment Procedure report will be issued in July 1967, to precisely define the rules for numerical reliability assessment.

I. RELIABILITY PROCEDURES EXHIBITS

The reliability procedures exhibits are as follows:

1. Exhibit A, Service Data Publications
2. Exhibit B, Failure Mode and Effect Analysis
3. Exhibit C, Example of Mathematical Model
4. Exhibit D, Failure Data Processing
5. Exhibit E, Parts History Data Processing

EXHIBIT A OF SECTION II
SERVICE DATA PUBLICATIONS

The contents and function of the service data publications are discussed.

A. ENGINE MAINTENANCE ANALYSIS INDEX

Information concerning all part discrepancies that were not the cause of a premature engine removal is contained in this data processing printout. An example is shown as figure 1. A part is considered to be discrepant when its condition has deteriorated to an extent sufficient to cause its removal from service operation. This information consists of the following details:

1. Name of discrepant part
2. Part number
3. Part disposition (scrapped, repaired, etc.)
4. Part section involved (leading edge, trailing edge, root, tip, etc.)
5. Part condition (broken, cracked, dented, eroded, etc.)
6. Findings (failure due to maintenance error, foreign material, etc.)
7. Date of part removal
8. Engine type, model and series
9. Total engine time
10. Engine time since last overhaul
11. Quantity of parts involved
12. Total part time
13. Engine installation (type of aircraft)
14. Engine position in aircraft
15. Reason for engine removal (overhaul, premature engine removal, etc.)
16. Operator of the engine
17. Part serial number

The engine maintenance analysis information is the primary source of service experience that is used to evaluate part durability. This information is analyzed statistically by the Reliability Groups to assess the part mortality distributions and determine the service lives of the analyzed parts. An example of a failure distribution determined from this data utilizing Weibull analysis techniques is shown in figure 2 for the No. 4 bearing of the commercial version of the JT4 (J75) engine. The data consisted of discrepant bearings found during engine teardown of one commercial operator's fleet of 104 JT4 engines. The discrepancy data do not extend above 51% since all of the bearings in operation had not failed and many had total operating times in excess of the highest time discrepant bearing.

SERVICE ENGINEERING RECORDS

ZONE	PART NAME CODE	PART NUMBER		NATURE CODES	FINDINGS	SUMM DATE	ENGINE CODES	ENGINE NUMBER	ENGINE TIME RUN	ENGINE TIME TOTAL	EPA QTY	TOTAL PART TIME	INST CODE			OPERATOR CODE	MAN	RPT	PART SERIAL NO	CODE SHEET #	
-	136	316866	6	25633	00	34	191153	631111	3521	9884	1	9880	20	4	2	890	5253	#	146	59377	S
-	136	316866	6	25633	00	34	191153	631325	2383	10924	1	10320	20	1	6	890	6253R	#	116	62905	S
	136	316866	7	25633	00	34	191153	631319	2667	10040	1	9790	20	1	6	890	5253M	#	144	9741	S
-	136	316866	6	25633	00	44	191153	630154	2313	9646	1	9640	20	3	6	890	5253R	#	157	65011	S
-	136	316866	6	25633	00	44	191153	633117	1947	7508	1	7500	20	1	Q	890	3253R	#	210	65133	S
	136	316866	6	25633	00	44	191153	629181	3279	7567	1	8440	20	4	N	890	5253	#	179	693[illegible]6	S
	136	316866	6	25633	00	44	191153	630613	2390	10334	1	10330	20	3	6	890	6253M	#	136	69632	S
	136	316866	6	25633	00	44	191153	632837	3104	8338	1	8690	20	6	5	890	3253R	#	193	90927	S
	136	316866	6	25633	00	54	191153	629179	3443	10073	1	8770	20	3	2	890	5253	#	155	73066	S
	136	316866	6	25633	00	64	191153	631108	3788	10983	1	10980	20	2	2	890	5283	#	172	73316	S
	136	316866	6	25633	00	64	191153	632959	3191	8510	1	10390	20	1	1	890	3253	#	132	74102	S
	136	316866	6	25633	00	74	191153	629177	3513	10822	1	10000	20	2	1	890	5253	#	107	80290	S
	136	316866	6	25633	00	74	191153	631854	3603	9507	1	9600	20	1	2	890	4253	#	105	80562	S
	136	316866	6	25633	00	74	191153	630325	1984	10902	1	5620	20	3	6	890	6253M	#	205	90438	S
	136	316866	6	25633	00	84	191153	631843	3702	9575	1	7560	20	1	[illegible]	890	4253	#	101	90760	S
16	136	316866	6	67633	00	94	191153	626890	3723	11683	1	9380	20	4	2	890	6253	#	193	99818	S
16	136	316866	6	25633	00	94	191153	629688	4170	9712	1	9710	20	1	2	890	4253	#	192	69	S
	136	316866	6	25633	00	94	191153	629409	4031	11784	1	11610	20	4	2	890	6253	#	112	4934	S
	136	316866	6	67633	00	94	191153	630160	2383	10956	1	9910	20	4	6	890	6253M	#	124	5723	S
	136	316866	6	25633	00	104	191153	632839	3487	9424	1	11630	20	3	2	890	3253	#	154	3641	S
	881	316881	R	1	CB	14	191153	627902	4039	10419	1	10410	20	4	1	890	6148	#	185	72861	S
	881	322141	6	DT 83	00	54	191153	629179	3443	10073	1	10070	20	3	2	890	5103	#	107	73012	S
	881	322141	6	79448	00	64	191153	631323	3565	10580	1	10580	20	1	2	890	5104	#	156	73509	S
	881	322141	6	83515	00	74	191153	629177	3513	10822	1	10820	20	2	1	890	5103	#	161	80236	S
	881	322141	6	83515	00	94	191153	629409	4031	11784	1	11780	20	4	2	890	6104	#	118	4879	S
-	881	322141	6	82516	00	14	191153	630833	3522	9351	1	9350	20	1	N	890	5104	#	144	36519	S
-	881	322141	6	E6516	00	24	191153	630882	3994	9627	1	9620	20	3	1	890	5104	#	134	50062	S
-	881	322141	6	83516	00	34	191153	629909	4095	10078	1	10070	20	3	2	890	5104	#	149	59104	S
-	881	322141	6	D8516	00	34	191153	631111	3521	9884	1	9880	20	4	2	890	5104	#	146	59322	S
-	881	322141	6	83516	00	34	191153	629056	3682	11215	1	11210	20	1	N	890	6104	#	103	62647	S
	881	322141	6	79516	00	74	191153	631854	3603	9507	L	9500	20	1	2	890	4104	#	195	80507	S
11	881	322141	6	E6516	00	94	191153	626890	3723	11683	1	11680	20	4	2	890	6103	#	155	99764	S
	881	322141	7	33633	00	34	191153	631319	2667	10040	1	10040	20	1	6	890	5103M	#	166	9715	S
-	452	332590	P	KA 85	00	34	191153	629056	3682	11215	1	11210	20	1	N	890	6400	#	103	62641	S
	452	332590	6	79448	00	64	191153	631323	3565	10580	1	8910	20	1	2	890	5400	#	102	73503	S
	452	332590	6	79448	00	64	191153	631108	3788	10983	1	10980	20	2	2	890	5400	#	171	73255	S

Figure 1. Engine Maintenance Analysis Index - Sample Printout

FIIA

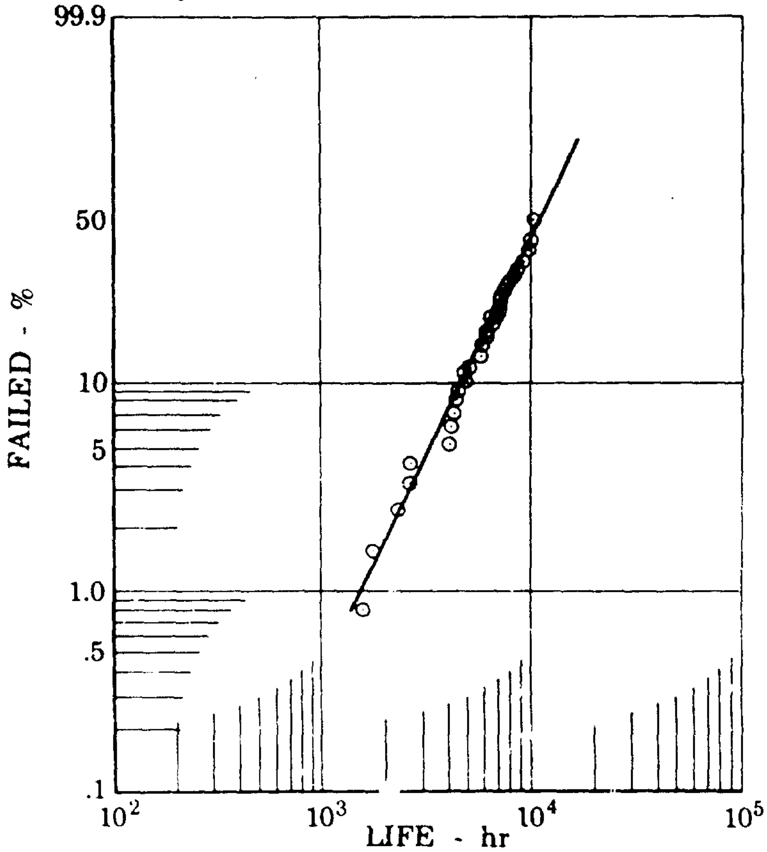


Figure 2. Weibull Plot of JT4 No. 4 Bearing

FD 17551
FIIA

Similar studies have been conducted on many other parts of the engine, such as,

1. Turbine blades
2. Combustion chambers
3. Main rotor spacers
4. Diffuser cases and
5. All main shaft bearings, etc.

The part durability evaluations that result from these studies are used to evaluate design criteria and to influence new designs.

B. INFLIGHT DISCREPANCY INDEX

The inflight discrepancy index is a data processing printout which is generated periodically and upon demand. The information contained within the index is coded and is presented in a form similar to figure 1. The following information is presented for each inflight shutdown event:

1. Inflight shutdown cause (chargeable or non-engine-chargeable)
2. Part charged with shutdown (No. 1 bearing, diffuser case, etc.)
3. Engine flight discrepancy indication (vibration, overtemperature, etc.)
4. Engine disposition after flight (engine removed, continued in service, etc.)
5. Flight discrepancy results (shutdown, not shutdown, etc.)
6. Aircraft flight attitude at failure (climb, cruise, descent, etc.)
7. Power lever setting at onset of flight discrepancy (acceleration, deceleration, steady state, etc.)
8. Date of shutdown
9. Engine model
10. Engine number
11. Engine time since last overhaul
12. Quantity of parts involved
13. Total part time
14. Engine installation
15. Engine position in aircraft
16. Airline operating the engine

The information is used to monitor the inflight shutdown experience of all Pratt & Whitney Aircraft engines and to determine the inflight shutdown rates for the engine components and parts. These calculated rates are used for reliability predictions and assessments.

C. PREMATURE ENGINE REMOVAL INDEX

All instances of premature engine removals that occur in Pratt & Whitney Aircraft engines in service are recorded in this data processing printout. This information is presented in a form similar to figure 1 and consists of the following details:

1. Premature engine removal cause (part charged)
2. Part number of primary failure
3. Part disposition (scrapped, repaired, etc.)

4. Part section involved (leading edge, trailing edge, root, tip, etc.)
5. Part condition (broken, cracked, dented, eroded, etc.)
6. Findings (failure due to maintenance error, foreign material, etc.)
7. Date of removal
8. Engine type, model, and series
9. Engine serial number
10. Total engine time
11. Engine time since last overhaul
12. Quantity of parts involved
13. Total part time
14. Engine installation (type of aircraft)
15. Engine position in aircraft
16. Operator of the engine
17. Part serial number

These data are used to evaluate the premature engine removal rates for all Pratt & Whitney Aircraft engines and parts. These rates are used for reliability predictions and assessments. Since premature engine removals are a major indicator of engine reliability and availability, it is important that the occurrences of all removals be carefully documented.

D. ENGINE REMOVAL INDEX

The engine removal index contains an entry for each time an engine is removed from an aircraft for both scheduled and unscheduled removals. This index is in the form of a data processing printout of which an example is illustrated in figure 3.

ZONE	PART NAME CODE	PART NUMBER		FAILURE CODES				ENGINE NUMBER	ENGINE TIME RUN	ENGINE TIME TOTAL	EPA QTY	TOTAL PART TIME	INST CODE			OPERATOR CODE	MAN	PART SERIAL NO		
41	739	372456	6	1 107 85	00	24	231123	610880	3190	9681	1	UNK	20	3	L	650	A084695•		3674L	L
11	83	335750	6	1 1 85	00	104	231123	610880	5133	11624	1	UNK	20	3	L	650	E209094•		1763L	LE
60	325	399600	5	1 1457	52	64	231123	610881	2425	9240	1	9260	20	1	L	650	A209414•		8193L	L
41	739	372456	6	1 107 85	00	104	231123	610881	2934	9770	1	UNK	20	1	L	650	A084790•		1671L	L
60	10	399600	5	1 1457	32	25	231123	610881	4205	11030	1	11030	20	3	L	650	E209015•		2076L	L
98	309	399900	3	3 1144	55	15	231123	610887	4134	13913	1	13910	14	X	6	650	A209430•		4228	S
98	309	399600	5	3 1144	55	74	231123	610894	2487	12362	1	12300	14	X	6	650	A209379•		26781	S
98	309	399800	5	3 1144	55	34	231123	610895	4201	9903	1	9900	14	X	6	650	A209346•		16591	S
98	309	399600	8	2 1140	55	84	231123	610895	5592	11211	1	11210	14	X	K	650	A209434•		43570	S
25	776	331994	6	1 1033	00	14	231123	610896	2164	10207	1	UNK	14	4	L	650	A102810•		2002L	L
41	58	411863	6	1M5526	00	44	231123	610896	3179	11222	1	UNK	14	4	L	650	E084052•		5316L	L
98	309	399800	8	2 1140	55	94	231123	610897	9119	11905	1	11900	14	X	K	650	A359021•		24011	S
98	309	399600	5	3 1144	55	124	231123	610897	2379	14285	1	14280	14	X	6	650	A084845•		1840	S
25	58	310610	7	158 52	00	14	231113	610921	3979	11130	1	UNK	14	3	L	650	A102842•		3541L	L
98	309	399600	8	2 1146	55	104	231123	610921	5790	12951	1	12950	14	X	K	650	A209442•		47874	S
64	443	453379	6	1 1320	07	74	231123	610922	2860	13247	1	UNK	14	1	L	650	A209418•		8245L	L
98	309	399600	5	3 1144	55	24	231123	610926	4149	10536	1	10530	14	X	6	650	A209358•		12470	S
98	309	399800	8	2 1140	55	74	231123	610926	5363	11750	1	11750	14	X	K	650	A209400•		29714	S
41	735	372456	6	1 107 85	00	14	231123	610937	3813	8934	1	UNK	20	X	L	650	A102836•		3644L	L
98	309	399600	8	2 1140	55	104	231123	610957	5787	10966	1	10960	20	X	K	650	A209442•		47873	S
98	309	399600	5	3 1144	55	84	231123	610958	2439	10869	1	10860	20	X	6	650	A209426•		38446	S
98	309	360700	8	2 1457	55	14	231103	610959	4782	9066	1	9060	20	X	K	650	A209337•		11270	S
15	719	316223	7	186 15	00	84	231123	610959	1564	10630	1	UNK	20	X	L	650	E209012•		8020L	L
98	309	399800	5	3 1144	55	124	231123	610959	2481	11547	1	11540	20	X	6	650	A209448•		169	S
98	309	360700	8	2 1457	55	24	231103	610961	4696	9460	1	9460	20	X	P	650	A209340•		13324	S
98	369	399800	5	3 1144	55	114	231123	610961	2417	11077	1	11070	20	X	6	650	A209645•		168	S
5	240	310940	7	1 1 32	00	14	231123	610965	4948	9694	1	UNK	14	4	3	650	A102826•		2196L	L
55	92	399600	6	1 1600	00	94	231123	610965	1954	11649	1	11640	14	1	L	650	A209432•		1019L	L
25	58	310610	7	1 1152	00	114	231123	610965	2444	12139	1	7380	14	1	L	650	A084618•		2107L	L
41	58	411C03	6	1M5526	00	24	231113	610968	3532	10531	1	UNK	14	1	L	650	E084028•		2784L	L
11	83	335750	6	1 1 85	00	44	231113	610968	3808	10807	1	UNK	14	1	L	650	E084046•		3865L	L
98	909	399700	6	3 1457	55	64	231113	610968	4435	11435	1	11430	14	X	4	650	A209368•		26287	S
55	92	425846	6	1M5633	00	94	231113	610968	5194	12194	1	UNK	14	1	L	650	A084755•		1270L	L
98	309	399800	6	3 1457	55	14	231123	610973	3818	9484	1	9480	14	X	4	650	A209332•		7295	S
98	309	399600	8	2 1140	55	74	231123	610973	5349	11017	1	11010	14	X	K	650	A209417•		50231	S
98	309	399600	6	3 1457	55	14	231123	610974	4006	9903	1	9900	14	X	4	650	A209333•		7294	S

Figure 3. Engine Removal Index - Sample Printout

The following detailed information is contained in each entry:

1. Date of engine removal
2. Engine type, model, and series
3. Engine serial number
4. Total engine time
5. Engine time since last overhaul
6. Engine installation (type of aircraft)
7. Engine position in aircraft
8. Reason for engine removal (premature engine removal, overhaul, etc.)
9. Operator of the engine

This information is used to ascertain the history of an engine and to maintain accurate records of individual engine operating time. This operating time information is used to estimate the total operating times on parts that have not failed and, thereby, aid in the determination of accurate failure distributions.

E. INFLIGHT SHUTDOWN AND PREMATURE ENGINE REMOVAL SUMMARIES

These summaries provide a means of quickly evaluating the service experience of any Pratt & Whitney Aircraft engine part. The data are presented in tabular form with the engine part and the number of failures listed on a monthly basis for engines in military, commercial, and industrial service. The number of engine operating hours accumulated during each month of operation is also presented. Therefore, a failure rate check can rapidly be made on a monthly basis to determine whether the occurrence of a specific problem is increasing or decreasing.

F. ENGINE MAINTENANCE ANALYSIS REPORTS

In addition to the above sources of information, special component failure and removal reports are generated to summarize the service experience of troublesome parts. Some of the problem areas that have been treated in this way are as follows:

1. Compressor inlet case discrepancies
2. Compressor rotor disk spacer cracking
3. Fuel control discrepancies
4. Compressor intermediate case oil leakage
5. Engine vibration
6. Accessory drive gear bearing failures
7. Fuel pump discrepancies

These special reports are published bimonthly under the title of Engine Maintenance Analysis Reports. The information contained within these reports is used to rapidly evaluate part durability and to keep cognizant engineering personnel informed about the service experience of specific engine parts.

Figure 4 illustrates how the Design Reliability Group utilizes the information contained in these documents to determine the exact nature and analysis of any service-connected incident.

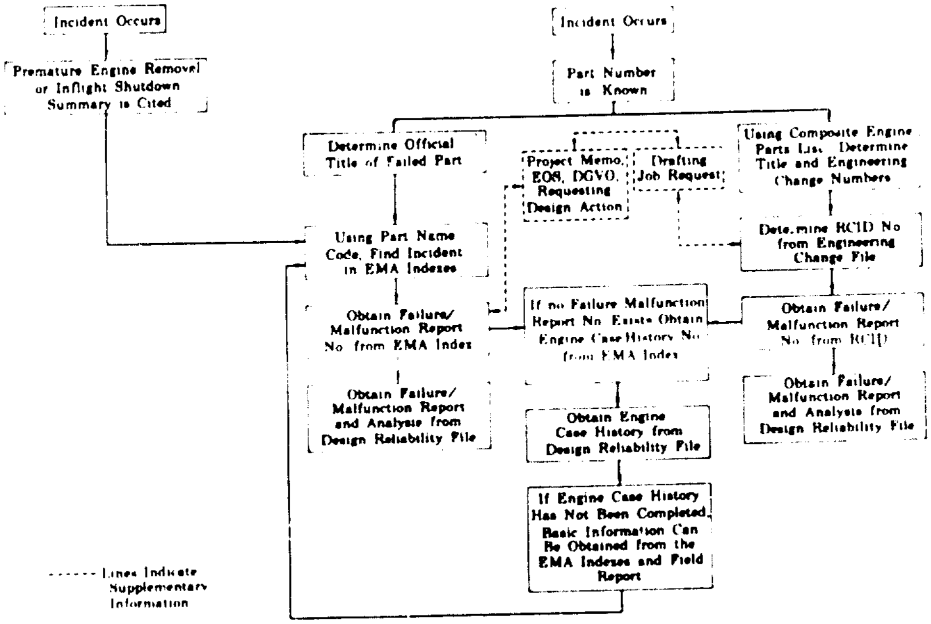


Figure 4. Design Reliability Action

FD 17552
FIIA

EXHIBIT B OF SECTION II
FAILURE MODE AND EFFECT ANALYSIS

A. GENERAL

The FMEA is an engineering design parameter in the same sense that other product characteristics are design parameters. Accordingly, the procedures used for accomplishing the FMEA parallel those used in arriving at other characteristics of parts anticipated in their application. The procedures described herein are general in coverage and will be used as a guide. The Design Reliability Group conducts the FMEA with the Design Engineer and Project Engineer as principal participants. Specialists in performance, metallurgy, controls, safety, aircraft performance and other characteristics contribute as required.

B. FAILURE EVENTS

Failure criteria events for early editions of the FMEA are inflight engine shutdown, inability to obtain selected augmented thrust, premature engine removal and unsafe conditions. Later editions of the FMEA will contain other events such as delays in dispatch and turnaround time, inlet failure induced by engine failure, excessive cruise TSFC, and others.

C. FAILURE MODE INDEX NUMBERS

The Reliability Block Diagrams, described in Section II, paragraph E5, provide the basic structure of the FMEA. Each block on the second and third level of the diagram provides an identification number divided into (1) major engine section, (2) component or assembly within major section, and (3) subassembly or detail part. Thus the number 7.7.0 would indicate the seventh component in the seventh major engine section, the first stage turbine disk. The failure mode index number is constructed from the block diagrams identification number by adding a fourth number that indicates a particular type of failure mode from a library of all possible types of failure modes. Thus the number 7.7.0.11 indicates rupture of the first stage turbine disk.

The Failure Mode Index Numbers are a common link between the Block Diagrams, the FMEA, the Mathematical Model and the Development Reliability Group Reliability Problem Files.

D. FMEA FORMAT

The Phase II-C FMEA format is illustrated in Section II by figure 17, sheet 1. The first column, ITEM, contains the Reliability Block Diagram nomenclature and identification number. The FUNCTION column is intended to describe the principal function(s) of the subassembly in the aircraft mission.

1. Failure Mode

The FAILURE MODE column contains a brief description of all potential component or part failures and/or malfunctions assumed to have occurred. The number of different types of failure modes are restricted to those "most likely to occur" as determined from development and/or field exper-

ience on similar or like parts in the same environments. It also includes consideration of additional modes of failure peculiar to this application and environment which may or may not have been experienced previously. However, secondary modes of failure are included where such effects are critical. The failures considered are assumed to be the only failures that have occurred, that is, each failure and its effect is considered to be the only failure in the system.

The "mode of failure" best describes the physical manner in which the initial failure occurs in a way in which the strength capability or durability may be exceeded in terms of geometric or material properties. The physical description may consist of describing the failure mode and mechanisms as one would expect to actually see on the failed parts. A failure may be defined as any incident or event which occurs to prevent the component or part to perform its intended function, in its known environment, within established limits for a given period of time and/or cycles.

Examples of failure modes and mechanisms are as follows:

1. Mechanical fatigue (pitting and/or spalling, cracking, flaking, etc.), low cycle fatigue (cyclic stress), combined stress (compression, tension, and shear), stress rupture (tension, compression, etc.), tension, compression, shear, torsion, creep (thermal growth, plastic deformation, strain, slip, etc.), corrosion (fretting, galling, galvanic action, intergranular, stress, etc.), erosion (particle, climatic, etc.), excessive wear (rubbing, abrasion, smearing, etc.), distortion (buckling, compression, etc.), loss of retention (loosening, relaxation, yield, etc.), loss of function (plugging, leakage, fails open, fails closed, etc.), contamination (dirt, sand and dust, foreign particles, etc.), indentation (brinelling, impact, etc.), etc.

2. Electrical Open, short, drift, distortion, electrical overload, loss of insulation, noise interference, radiation, ionization, arcing, contact bounce, thermal shock, etc.

3. Chemical Oxidation, reduction, deposition, corrosion, sublimation, deterioration, plating, fungus, etc.

2. Failure Effect on Subsystem and Engine

The columns Failure Effect on Subsystem and Engine is a description of the effects and consequences of each failure mode on the function at the subsystem level (component or part) and the system level (powerplant or end-item). Secondary failures of the components or parts that would result due to the assumed failure mode are also described. This is necessary since many system failures are initiated at the part level.

It may be necessary to best describe the effect by describing the order of events, starting at the lowest level or first occurrency to failure, then led up to the effect at the system level.

3. Method of Detection, Failure Effect on Aircraft, and Crew Action Required

The three columns, Method of Detection, Failure Effect on Aircraft, and Crew Action Required, provide a concise statement of the expected chain of events after the failure mode occurs. The detection method describes the means by which the failure mode and/or the failure causes are detected, or parameters which can be monitored over a period of time to indicate malfunctions by trend analysis.

a. Methods of Detection

The methods of detection fall into three broad areas as follows:

1. Manufacturing or Process - Indicates how the failure mode and/or causes are being monitored or controlled in the manufacturing or fabrication process. This would apply to those failure modes and causes that are or can be minimized or eliminated in the manufacturing process such as X-ray of welded and brazed joints, leak or proof pressure checks, electrical continuity or dialectric checks, controlled torque, material control, or other inspection orientated checks.

2. System Level - Indicates if a pilot readout can be used that would allow the pilot or crew to take appropriate corrective action to prevent a critical or catastrophic failure. Examples of readouts are: pressure gages, temperature gages, RPM indicator, vibration meter, indicator lights, etc.

3. Monitor Trend Parameters - Two general areas, performance and mechanical parameters, will be monitored by the AIDS System.

   a. Performance Parameters-Changes in

      Exhaust Gas Temperature
      Fuel Flow
      Fan Speed
      High Pressure Compressor Speed
      Nozzle Area
      etc

   b. Mechanical Parameters

      Engine Vibration
      Breather Pressure
      Oil Consumption
      Oil Contamination
      Fuel Pressure
      etc

b. Failure Effect on the Aircraft

The failure effect on the aircraft column includes the failure events premature engine removal, inflight engine shutdown and the in-

ability to obtain selected augmented thrust. Other events such as delays in dispatch and turnaround time and reduced performance should be included. Precise quantitative descriptions are desired whenever possible.

c. Hazard Classification

A second page, figure 11, sheet 2 of Section II, will be added to the third edition of the FMEA. The Hazard Classification column is used for the purpose of assessing the design from a criticality point of view by classifying the assumed failure modes in four general categories: minor, major, critical, or catastrophic. In mechanical equipment a component or part failure need not be a critical system failure. The purpose of this column is to properly classify each failure effect at the system level. The applicable number is inserted in this column against the particular failure mode as follows:

Class I - Minor - A noncritical failure that has no significant effect on the ability of the system to perform its intended function satisfactorily. This type of failure may be due to personnel errors, design deficiency, or subsystem-component malfunction and will not result in a major system degradation and it will not produce system functional damage or contribute to system hazard or personal injury.

Class II - Major - A noncritical failure due to personnel error, design deficiency, or subsystem-component malfunction which will degrade the system to some extent without major system damage or personal injury but can be adequately counteracted or controlled.

Class III - Critical - A critical failure due to personnel error, design deficiency, or subsystem-component malfunction which will degrade the system causing personnel injury, substantial system damage, or result in an unacceptable hazard necessitating corrective action for personnel and subsystem survival.

Class IV - Catastrophic - A critical failure due to personnel error, design deficiency, or subsystem-component malfunction which will produce severe degradation of the system which will result in loss of the system or death, or multiple deaths or injuries.

d. Design Philosophy to Preclude Failure

The Design Philosophy to Preclude Failure is a brief description of the design philosophy or design approach used to eliminate or minimize the occurrence of the assumed failure mode. The objective is to describe the design concepts utilized to control the adverse system effects such that the probability of failure is reduced to an extremely low level. The design philosophy may include one or more of the following: material selection and control, quality control, adequate stress margins, tolerance control, control of maintenance action, etc.

e. Design Philosophy to Reduce Hazard

The Design Philosophy to Reduce Hazard column is only employed for critical and catastrophic failure modes to describe the action taken to reduce the classification of these failure modes. It also includes any compensating provisions that are inherent in the design such as component redundancy, alternate operating modes, or failsafe features. These features are intended to prevent failures in the catastrophic mode.

EXHIBIT C OF SECTION II
AN ILLUSTRATION OF THE JTF17
MATHEMATICAL MODEL

In the example that follows, the preliminary JTF17 mathematical model has been exercised to produce the criticality analysis of the turbine section for premature engine removal. This analysis is based on an apportionment of the turbine component failure rates to the turbine failure modes, table 1.

Table 1 lists the failure modes to be ranked in the criticality analysis. Column three provides the estimate of failure frequency for each mode, frequently, rarely or never. The mathematical model assigns a numerical interpretation to these frequencies; the ratio of frequently to rare is 10 to 1, never has probability zero.

Table 1. Reliability Apportionment

ENGINE SECTION : TURBINE
FAILURE EFFECT : PREMATURE ENGINE REMOVAL
MISSION SEGMENT: OVERALL MISSION

Item Number	Item Name	Reliability Apportionment Rate/1000 hrs.	Failure Mode	Failure Mode Number	Failure Frequency	Numerical Interpretation*	Probability of Failure Effect
7.1	1st stage blade	.02901	Airfoil separation	7.1.0.1	Frequently	$10xP_{7.1.0}$	Probable
			Root attachment sep.	7.1.0.2	Rarely	$P_{7.1.0}$	Probable
7.2	2nd stage blade	.00000	Tip shroud looseness	7.2.0.3	Never	0.0	Improbable
			Root attachment sep.	7.2.0.2	Never	0.0	Improbable
			Airfoil separation	7.2.0.1	Never	0.0	Improbable
7.3	3rd stage blade	.01102	Tip shroud looseness	7.3.0.3	Rarely	$P_{7.3.0}$	Improbable
			Root attachment sep.	7.3.0.2	Rarely	$P_{7.3.0}$	Improbable
			Airfoil separation	7.3.0.1	Rarely	$P_{7.3.0}$	Improbable
7.4	1st stage vane	.00135	Bowing	7.4.0.8	Frequently	$10xP_{7.4.0}$	Improbable
			Burnthrough	7.4.0.7	Rarely	$P_{7.4.0}$	Improbable
			Cracking	7.4.0.9	Frequently	$10xP_{7.4.0}$	Improbable
			Wear from axial move.	7.4.0.5	Rarely	$P_{7.4.0}$	Improbable
7.5	2nd stage vane	.00027	Bowing	7.5.0.8	Rarely	$P_{7.5.0}$	Improbable
			Burnthrough	7.5.0.7	Rarely	$P_{7.5.0}$	Improbable
			Cracking	7.5.0.9	Rarely	$P_{7.5.0}$	Improbable
			Wear from axial move.	7.5.0.5	Rarely	$P_{7.5.0}$	Improbable
7.6	3rd stage vane	.00000	Bowing	7.6.0.8	Never	0.0	Improbable
			Burnthrough	7.6.0.7	Never	0.0	Improbable
			Cracking	7.6.0.9	Never	0.0	Improbable
			Wear from axial move.	7.6.0.5	Never	0.0	Improbable
7.7	1st stage disk	.00000	Rupture	7.7.0.11	Never	0.0	Improbable
7.8	2nd stage disk	.00000	Rupture	7.8.0.11	Never	0.0	Improbable
7.9	3rd stage disk	.00055	Rupture	7.9.0.11	Rarely	$P_{7.9.0}$	Improbable
7.10	Hubs	.00000	Section separation	7.10.0.12	Never	0.0	Improbable
7.11	Shafts	.00000	Shaft Separation	7.11.0.13	Never	0.0	Improbable
7.12	Coupling tie bolts	.00000	Bolt separation	7.12.0.14	Never	0.0	Improbable
7.13	Inner air seal ring	.00108	Cracking	7.13.0.9	Rarely	$P_{7.13.0}$	Improbable
			Seal rub	7.13.0.10	Rarely	$P_{7.13.0}$	Improbable
7.14	Stationary outer shroud	.00672	Wear from airfoil rub	7.14.0.4	Rarely	$P_{7.14.0}$	Probable
			Wear from axial move.	.14.0.5	Frequently	$10xP_{7.14.0}$	Probable
			Erosion	7.14.0.6	Frequently	$10xP_{7.14.0}$	Improbable
			Burnthrough	7.14.0.7	Rarely	$P_{7.14.0}$	Improbable

* The probabilities are defined in terms of a rare event in each subsystem. The model provides the solution for this probability.

Column four lists the conditional probability that the failure mode will produce the failure effect; probable, improbable, and never. The mathematical model interprets these as probable is 0.80, improbable is 0.20 and never is zero. Later editions of the model will employ more sophisticated scales.

For each item the criticality is assigned by solving the equation below for P_{A_K}, the failure probability for one of the rare failure modes:

$$P(B_K) = \sum_{\substack{\text{all failure} \\ \text{modes } A_i}} \left[P(B|A_i)\ P(A_i) \right] = \sum_{\substack{\text{all failure} \\ \text{modes } A_i}} \left[P(B|A_i) \times K_i P_{A_K} \right]$$

where $P(B_K)$ is the reliability apportionment for subassembly K, A_K is a rare failure mode of subassembly K, $P(B|A_i)$ is the conditional probability of the failure effect (in this case, PER), given failure mode A_i has occurred, K_i is the relative failure frequency of occurrence for the i^{th} mode.

For example, the first stage turbine blade was assigned a reliability apportionment of .02901 failures per thousand hours. The criticality assigned to the two failure modes, Airfoil Separation and Root Attachment Separation, is found by:

$$.02901 = 0.8 \times 10\ P_{7.1.0} + 0.8 \times P_{7.1.0}$$

$$= 8\ P_{7.1.0} + 0.8\ P_{7.1.0}$$

$$= 8.8\ P_{7.1.0}$$

$$\therefore P_{7.1.0} = .003297$$

The criticality assignment for this turbine blade is:

Airfoil Separation Criticality $= (.8)\ (10)P_{7.1.0} = .02637$

Root Attachment Separation $= (.8)P_{7.1.0} = .00264$

The criticality ranking of failure modes for the turbine for premature engine removal is shown as table 2.

Table 2. Criticality Ranking

ENGINE SECTION : TURBINE

FAILURE EFFECT : PREMATURE ENGINE REMOVAL

MISSION SEGMENT: OVERALL MISSION

Failure Modes	Failure Mode Number	Effect Rate/1000 hrs.
1st stage blade airfoil separation	7.1.0.1	0.02637
Stationary outer shroud axial movement wear	7.14.0.5	0.00489
3rd stage blade tip shroud looseness	7.3.0.3	0.00367
3rd stage blade root attachment separation	7.3.0.2	0.00367
3rd stage blade airfoil separation	7.3.0.1	0.00367
1st stage blade root attachment separation	7.1.0.2	0.00264
Stationary outer shroud erosion	7.14.0.6	0.00122
1st stage vane bowing	7.4.0.8	0.00061
1st stage vane cracking	7.4.0.9	0.00061
3rd stage disk rupture	7.9.0.11	0.00055
Inner air seal ring cracking	7.13.0.9	0.00054
Inner air seal ring seal rub	7.13.0.10	0.00054
Stationary outer shroud airfoil rub wear	7.14.0.4	0.00049
Stationary outer shroud burnthrough	7.14.0.7	0.00012
2nd stage vane bowing	7.5.0.8	0.00007
2nd stage vane burnthrough	7.5.0.7	0.00007
2nd stage vane cracking	7.5.0.9	0.00007
2nd stage vane wear from axial movement	7.5.0.5	0.00007
1st stage vane burnthough	7.4.0.7	0.00006
1st stage vane wear from axial movement	7.4.0.5	0.00006
2nd stage blade tip shroud looseness	7.2.0.3	0.00000
2nd stage blade root attachment separation	7.2.0.2	0.00000
2nd stage blade airfoil separation	7.2.0.1	0.00000
3rd stage vane bowing	7.6.0.8	0.00000
3rd stage vane burnthrough	7.6.0.7	0.00000
3rd stage vane cracking	7.6.0.9	0.00000
3rd stage vane wear from axial movement	7.6.0.5	0.00000
1st stage disk rupture	7.7.0.11	0.00000
2nd stage disk rupture	7.8.0.11	0.00000
Hubs - section separation	7.10.0.12	0.00000
Shafts - shaft separation	7.11.0.13	0.00000
Coupling tie bolt separation	7.12.0.14	0.00000

PREVIOUS PAGE WAS BLANK, THEREFORE WAS NOT FILMED.

EXHIBIT D OF SECTION II
FAILURE DATA PROCESSING

Whenever a failure occurs on an experimental engine or component rig, the Experimental Engineer responsible for the test item initiates a failure report. On the failure report (figure 1) the engineer indicates the failure type and location, any unusual environmental conditions and the final disposition of the failed part or component, if known. The failure report is forwarded to the Development Reliability Group. The report is logged into the Reliability Data Bank and a serial number is assigned. A blank Failure Analysis Report form bearing the same serial number and identifying information, is sent to the cognizant Assistant Project Engineer. The Assistant Project Engineer completes the failure analysis report (figures 2a and b), indicating reason for failure, type of corrective action taken and final disposition of the part, if known. The completed report is then returned to the Development Reliability Group for distribution.

[X] INITIAL REPORT
[ ] REVISED REPORT
REFER TO F/M REPORT NUMBER ____

DATE 5-10-66
TIME 10:00
PREPARED BY D. MILLER
REPORT NUMBER S-6

PROJECT IDENTIFICATION

ENGINE TYPE	MODEL	ENGINE NO. OR COMPONENT IDENTIFICATION NO.	BUILD NO	RUN NO.
SST	JTF-17	FX-161	1	

FAILURE/MALFUNCTION DEFINITION

PART NAME	PART NO.	E/C LTR		SERIAL NO	NEXT ASSEMBLY NO.
1ST TURB. FT COVER PLATE	2115387			ADE 73	
ASSY. OR COMPONENT NAME	**ASSY. NUMBER**	**E/C LTR**	**GRP. NO**	**SERIAL OR I.D. NO.**	**NEXT ASSEMBLY NO.**
HIGH TURB. ROTOR	2120018				

[X] PART FAILURE [ ] ENGINE MALFUNCTION [ ] TEST FAC. EQUIP. MALFUNCTION
[ ] COMPONENT MALFUNCTION [ ] TEST INSTR. & CONTROL MALFUNCTION [ ] OPERATOR ERROR

OCCURRENCE DATE				RUNNING TIME TO F/M ON THIS TEST 11.63 HR.					TEST STAND NO
TIME	MONTH	DAY	YEAR	HOURS	MINUTES	SECONDS	CYCLES	OTHER	
	4	11	66	11	38				A-4

WAS TEST TERMINATED BY THIS F/M ? [ ] YES [X] NO

OCCURRED AT
[ ] ASSEMBLY [X] TEST [ ] PARTS INSPECTION [ ] INSTRUMENT OR FACILITY CHECK
[ ] BENCH OPERATION [ ] DISASSEMBLY [ ] PACKING & SHIPPING

FAILURE/MALFUNCTION DESCRIPTION (INCLUDE OPERATING CONDITIONS, INDICATIONS, MANNER OF DETECTION)

DISASSEMBLY SHOWED THE COVER PLATE KNIFE EDGE SEALS TO HAVE CRACKED AT TEST. 5 AXIAL CRACKS WERE NOTED AROUND SEAL HOOP

REPAIR, REPLACEMENT OR DISPOSITION ACTION

[ ] REINSTALL W/O REPAIR OR REOP [ ] REINSTALL W/REOP [ ] RETURN TO VENDOR [ ] SCRAP
[ ] REINSTALL W/REPAIR [ ] TO USED STORES [ ] TO DORMANT STORES [X] REFER FOR ANALYSIS
[ ] QUALITY REVIEW

REPLACEMENT P/N OR ASSY NO.	E/C LTR	GRP NO	S/N OR I.D. NO	REMARKS
ITEM 14(2118377) L-213086-1			ADE 589	

FOR RELIABILITY GROUP USE ONLY RECEIVED BY L. QUIRION DATE 5-11-66

Figure 1. Failure/Malfunction Report

☒ INITIAL ANALYSIS ☐ REVISED ANALYSIS REFER TO F/M REPORT NUMBER	DATE 6-3-66 TIME	REPORT NUMBER S-6
	F/M REPORT PREP'D BY D. MILLER	

PROJECT IDENTIFICATION

ENGINE TYPE	MODEL	ENGINE NO. OR COMPONENT IDENTIFICATION NO.	BUILD NO	RUN NO.
SST	JTF-17	FX-161	1	

FAILURE/MALFUNCTION DEFINITION

PART NAME	PART NO.*	E/C LTR		SERIAL NO	NEXT ASSEMBLY NO
1ST TURB FT. COVER PLATES	2119387			ADE 73	
ASSY. OR COMPONENT NAME	ASSY. NUMBER*	E/C LTR	GRP NO	SERIAL OR I D NO	NEXT ASSEMBLY NO
HIGH TURB. ROTOR	2120015				

FOR SECONDARY FAILURE DO NOT COMPLETE BELOW

FAILURE/MALFUNCTION ANALYSIS

TYPE OF FAILURE OR MALFUNCTION, CAUSE, STARTING POINT:
CIRCLE THE ONE APPLICABLE ITEM UNDER EACH OF THE THREE COLUMN HEADINGS ON THE REVERSE SIDE

STATEMENT OF SPECIFIC FINDINGS:

NUMEROUS CRACKS WERE FOUND IN 1ST AND 2ND KNIFE EDGES (TOWARD THE FRONT OF ENGINE) OF THE LABYRINTH SEAL. SEVERAL CRACKS PROPAGATED FROM THE 1ST KNIFE EDGE INTO THE SEAL LOOP. MDL

(CONTINUE ON REVERSE SIDE)

*THIS ITEM WAS X WAS NOT ____ RELEASED TO THE BILL OF MATERIAL

CORRECTIVE ACTION

☒ DESIGN CHANGE REQUESTED (CHECK AS APPLICABLE) ☐ QUALITY ASSURANCE ACTION REQUESTED

E.O.S. OR E/C NO. ____ ☐ NO ACTION REQUIRED

TYPE OF CORRECTIVE ACTION A NEW SEAL WAS AVAILABLE FOR THE HIGH TEMP. TURBINE DESIGN. THE KNIFE EDGE SEAL CLEARANCE WAS INCREASED FROM .025 (NOM) TO .035 (NOM) AND A DAMPER WAS RIVETED ON. REF. L-213086 CS E-261047 AND 261160

ANALYSIS COMPLETED BY: J.D. GOOLSBAY DATE 6-6-66 TIME ____

FOR RELIABILITY GROUP USE ONLY

RECEIVED BY LOUISE QUIRION DATE 6-6-66

CLASSIFIED BY ____ DATE ____ CLASSIFICATION OF F/M

Figure 2a. Failure Malfunction Analysis

FIID

MALFUNCTION (SHUTDOWN WITH NO PARTS BREAKAGE) OR	TYPE OF PART FAILURE	FAILURE STARTING POINT	MALFUNCTION/FAILURE CAUSE
OPERATION BELOW SPEC LIMIT	FATIGUE	EDGE	MATERIAL DEFECT
OPERATION ABOVE SPEC LIMIT	TENSION	SLOT	MACHINING DEFECT
ERRATIC RESPONSE	TORSION	WALL	IMPROPER HEAT TREAT
OSCILLATION	SHEAR	HOLE	IMPROPER CHEMICAL PROCESS
LEAK	WEAR	TIP	WELD/BRAZE DEFECT
NO STARTING ABILITY	CORROSION	WEB	FAULTY ASSEMBLY
STALL	EROSION	DIELINE	TESTING OVERSTRESS (INTENTIONAL)
INCORRECT SPEED	RUB	AIRFOIL	WEAROUT (NORMAL)
INCORRECT TEMPERATURE	SKID	SHROUD	OVERTEMPERATURE
INCORRECT PRESSURE	SCORE	FILLET	OTHER PART FAILURE
NO IGNITION	SCUFF	CORNER	UNDEVELOPED DESIGN
PERFORMANCE DECAY	GALL	BRAZE OR WELD	FOREIGN MATERIAL
LOSS OF INSTRUMENTATION	THERMAL SHOCK	SHEAR SECTION	TEST EQUIPMENT
LOSS OF FUEL SUPPLY	LEAK	THREAD	FAULTY INSTRUMENTATION
LOSS OF ELECTRICAL SUPPLY	CRACK	ROOT	IMPROPER ADJUSTMENT
OTHER (DESCRIBE)	OTHER (DESCRIBE)	ROLLER	FAULTY INSTALLATION
		RACE	OTHER (DESCRIBE) HIGH ORDER RESONANCE
		BALL	
		CAGE	
		SUPPORT	
		FLANGE	
		FACE	
		OTHER (DESCRIBE)	

ANALYSIS SHOWED THE 1ST AND 2ND KNIFE SEALS RUBBED, MELTED THE METAL AND RE-SOLIDIFIED (CAST STRUCTURE) ON THE EDGE OF THE SEALS. THIS RESULTED IN A REDUCTION OF PROPERTIES AND CRACKS WERE FORMED AT THE SEAL EDGE AND PROPAGATED BY HIGH ORDER OF RESONANCE (APPROX. 6000 CPS). REF. MDL REPORT NO. 11864.

Figure 2b. Failure/Malfunction Analysis

FIID

The failure data is processed on IBM cards as input to the computerized reliability data bank. The data bank is maintained on the IBM 360 computer.

The Failure Report and Failure Analysis Reports are filed in the Development Reliability Group and duplicates are distributed as shown on figure 3.

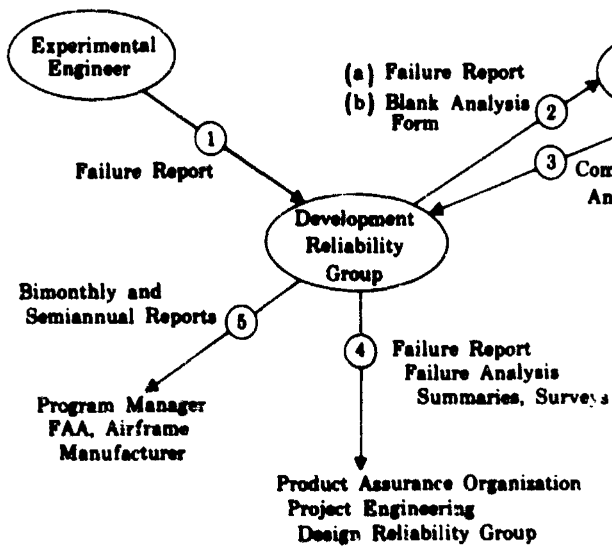


Figure 3. Failure Data Flow Chart FD 17553
FIID

Failure data summaries are completely computerized and may be tabulated by:

1. All failures of one type
2. All failures for a single engine build
3. All failures by part name, part number, or component

These summaries may be requested by any engineering group. A summary of failures is included in each Bimonthly and Semiannual Reliability Report. Typical JTF17 failure summaries from Phase II-C are shown in figures 4 and 5.

```
ENGINE PART FAILURE REPORT          JTF 17A FAILURE/MALFUNCTION ANALYSIS AND SUMMARY          02016607146

SUFX NO. CHG.LET.  PART NAME   PART NO.  ITM-QTY  ENG-BLD NO. TOT.TIME  TEST STND   F/A NO.  SER.NO.
      A            TIERED PRTR 2114256   020-020  FX16103     003590    A-4         S 0257   QTV020

INSPECTION DEVIATION - CIRCLE 9 AND 4 X 5
FAILURE TYPE - GALLING
FAILURE STARTING LOCATION - MAIN SKIN MATERIAL
REASON - MISCELLANEOUS - IMPROPER ASSEMBLY HANDLING
TYPE OF TEST - SEA LEVEL PERFORMANCE
PART DISPOSITION - REINSTALLED IN ENGINE OR RIG AS IS CONDITION

SUFX NO. CHG.LET.  PART NAME   PART NO.  ITM-QTY  ENG-BLD NO. TOT.TIME  TEST STND   F/A NO.  SER.NO.
                   BRG 4TH     2113296   001-001  FX16201     001962    A-3         S 7060   ABV025

FAILURE TYPE - WEAR
FAILURE STARTING LOCATION - OUTER RACE
TYPE OF TEST - SEA LEVEL PERFORMANCE
PART DISPOSITION - U.S. - DAMAGED

SUFX NO. CHG.LET.  PART NAME   PART NO.  ITM-QTY  ENG-BLD NO. TOT.TIME  TEST STND   F/A NO.  SER.NO.
                   BRKT BT     2121906            FX16103     003590    A-4         S 7064

FAILURE TYPE - STRESS-RUPTURE
FAILURE STARTING LOCATION - MAIN SKIN MATERIAL
TYPE OF TEST - SEA LEVEL PERFORMANCE
```

Figure 4. Engine Part Failure Report FIID

PART FAILURE SUMMARY

JTF 17A FAILURE/MALFUNCTION ANALYSIS *

1. TOTAL NUMBER OF PRIMARY FAILURES ACCUMULATED DURING THE PERIOD 020166 TO 071466 WAS 178

2. FAILURE TYPES ARE SUMMARIZED AS FOLLOWS	
FATIGUE	1
GALLING	3
STRESS RUPTURE	12
OVERHEATED	6
RUBBING	4
WARPAGE	2
WEAR	15
3. FAILURES STARTED IN THE FOLLOWING TYPICAL LOCATIONS	
AT LEADING EDGE	8
AT HOLE	1
IN ROOT SECTION	1
AT TIP	10
IN AIRFOIL	1
IN MAIN SKIN MATERIAL	9
AT SUPPORT DIAPHRAGM	1
IN FLANGE	1
4. DESIGN SYSTEM PROBLEMS	16
5. QUALI CONTROL PROBLEMS	16
6. PROBLEM NOT DEFINED	1

Figure 5. Part Failure Summary

EXHIBIT E OF SECTION II
PARTS HISTORY DATA PROCESSING

The Parts History system was put into operation in 1959 and has been used successfully for both the RL10 rocket engine and the JT11 turbojet engine. To adapt this system to the JTF17, a list of critical parts (figures 1 and 2) were compiled for serialization. This serialized Parts List was approved in January 1966.

JTF-17A SERIALIZED PARTS LIST

RELIABILITY PARTS HISTORY RECORD WILL INCLUDE ALL SERIALIZED PARTS DEFINED IN THE ATTACHED MASTER SERIALIZATION LIST.

CPID - INDICATES COMPONENT IDENTITY NUMBER REQUIRED-NOT SERIALIZED
* - INDICATES OBSOLETE PART NUMBER
$ - INDICATES A SERIALIZED DETAIL OF A SERIALIZED ASSEMBLY OR CPID
VENDOR- INDICATES VENDOR SERIAL NUMBER ONLY

DEFINITION OF ENGINE SECTION ZONE NUMBER

ZONE		A.P.F.
1.	FAN	G.PARKER
2.	NO.1 AND NO.2 BEARING INTERNAL OIL SYSTEM	C.BARNES
3.	HIGH COMPRESSOR	J.GILL
4.	NO.3 BEARING INTERNAL OIL SYSTEM	C.BARNES
5.	DUCT HEATER	H.FORD
6.	DUCT HEATER EXIT NOZZLE	B.CARPENTER
7.	DIFFUSER AND MAIN BURNER	W.COOPER
8.	TURBINE	F.KRENEK
9.	NO.4 BEARING INTERNAL OIL SYSTEM	C.BARNES
A.A.	MAIN GEARBOX	C.BARNES
A.B.	NO.1 SCAVENGE PUMP	C.BARNES
A.C.	REVERSER, REDUCTION GEARBOX	C.BARNES
A.D.	STARTER GEARBOX	C.BARNES
A.E.	MAIN OIL PUMP	C.BARNES
A.F.	MAIN OIL PUMP	C.BARNES
B.	OIL SYSTEM EXTERNAL COMPONENTS	C.BARNES
C.	HYDRAULIC COMPONENTS	J.MORTENSON
D.	FUEL COMPONENTS	
E.	PLUMBING	J.MORTENSON
F.	ELECTRICAL COMPONENTS	E.TAYLOR

Figure 1. JTF17A Serialized Parts List

FIIE

06/20/66 JTF17 SERIALIZED PARTS LIST PAGE

ALPHABETIC

PART NO	NOMENCLATURE	REMARKS	ZONE	ITM*QTY	DESCRIPTION
2118033	ADAPT SGBX		A	D01*001	ADAPTER-STARTER GEARBOX,ASYO
2116325	ADJUSTER		A	A01*001	ADJUSTER-.375-32-32X9.100
2116328	ADJUSTER		A	A02*002	ADJUSTER-.375-32-32X5.000
2116329	ADJUSTER		A	A03*001	ADJUSTER-.375-32-32X4.00
2117562	ADPT TUBE		4	1*001	ADAPTER-STRAIGHT,.500-20-20
2117582	ADPT TUBE		4	2*001	ADAPTER-STRAIGHT,1.0625-12-12
2117583	ADPT TUBE		4	3*001	ADAPTER-STRAIGHT,.5625-18-18
2117585	ADPT TUBE		4	4*001	ADAPTER-STRAIGHT .875-14-14
2116528	BELL CRANK		3	1*001	BELL CRANK-CPR STATOR LINKAGE
2116935	BELL CRANK		3	2*001	BELL CRANK-CPR STATOR
2116372	BLADE C3		3	3*090	BLADE-COMPRESSOR RTR 3 STAGE
2126403	BLADE C3		3	3*090	BLADE-COMPRESSOR ROTOR,3 STAGE
2126503	BLADE C3		3	3*090	BLADE-COMPRESSOR ROTOR,3 STAGE
2127303	BLADE C3		3	3*090	BLADE-COMPRESSOR ROTOR,3 STAGE
2116370	BLADE C4		3	4*100	BLADE-COMPRESSOR RTR 4 STAGE
2127304	BLADE C4		3	4*100	BLADE-COMPRESSOR ROTOR,4 STAGE
2116224	BLADE C5		3	5*114	BLADE-COMPRESSOR 5 STAGE
2127305	BLADE C5		3	5*114	BLADE-COMPRESSOR ROTOR,5 STAGE
2129005	BLADE C5		3	5*114	BLADE-COMP ROTOR,5 STAGE
2116564	BLADE C6		3	6*108	BLADE-COMPRESSOR,6 STAGE,ASYO
2116558	BLADE C7		3	7*110	BLADE-COMPRESSOR,7 STAGE,ASYO
2129007	BLADE C7		3	7*110	BLADE-COMP ROTOR,7 STAGE
2116397	BLADE C8		3	8*114	BLADE-COMPRESSOR RTR 8 STAGE
2122401	BLADE F1		1	1*044	FAN BLADE 1 STAGE
2126201	BLADE F1		1	1*044	BLADE-FAN ROTOR,1 STAGE
2118702	BLADE F2		1	2*074	FAN BLADE 2 STAGE
2118902	BLADE F2		1	2*074	BLADE-CPR RTR,2 STG.
2118401	BLADE T1		8	1*086	BLADE-TURBINE ROTOR,1 STAGE
2122201	BLADE T1		8	1*086	BLADE-TURBINE ROTOR,1 STAGE
2126301	BLADE T1		8	1*086	BLADE-TURBINE ROTOR,1 STAGE
2126401	BLADE T1		8	1*086	BLADE-TURBINE ROTOR,1 STAGE
2126501	BLADE T1		8	1*086	BLADE-TURBINE ROTOR,1 STAGE
2114502	BLADE T2		8	2*088	B' TURBINE MOTOR,2 STAGE
2114503	BLADE T3		8	3*076	BLADE TURBINE ROTOR,3 STAGE
0500536	BRG		A	C01*001	BEARING-BALL,40X68X15

Figure 2. JTF17 Serialized Parts List

FIIE

The establishment of the JTF17 Serialized Parts List initiated the serialization of critical parts. The serial numbers provide a unique identification so that, regardless of part number changes due to re-operations, the entire history of the part can be retraced. The Parts History System was put in operation in the JTF17 Project when the Serialized Parts List was approved.

The Development Reliability Group is responsible for the Parts History system. To obtain data for each part, a Reliability Coordinator is assigned to each test rig or engine. The Coordinator checks the Experimental Parts Requisition forms (figure 3) and compares them with the parts list requested by Project Engineering. Differences are resolved with the Experimental Engineers.

EXPERIMENTAL PARTS REQUISITION OR SUPPLEMENT

DATE 6/24/65	PULL FROM F/S	DO NOT USE 21 SF	TRANSFER TO
PROJ ORDER NO. [illegible]	ENGINE TYPE SST	ENGINE NO. FX14300 / ENGINE SECTION ENG ASSY	DELIVER TO ASSEMBLY
ASSEMBLY NO. A2120000	REQUESTED BY N PORTO	EXP. ENGR. APPROVAL BY	WITHDRAWAL AUTH. BY [illegible]

CAN-CEL	QUANTITY	DEL'D	INV	PART NUMBER	CHG LTR	PART NUMBER SUFFIX	INSP KEY	REMARKS AND SPECIAL MARKINGS	SOURCE	PART NAME	LOCATION
	1	—	N/S	2117596					—	MANIFOLD	—
	2	2		2117558				[illegible]	[illegible]	METERING PLUG-.064X.25	[illegible]
	2	2		2117559				[illegible]	[illegible]	METERING PLUG-.090X.31	[illegible]
	1	1		2117566				[illegible]	[illegible]	BRACKET-ANGLE	[illegible]
	1	1		2117567				[illegible]	[illegible]	BOLT-MA..190-32X.533,D	[illegible]
	4	4		2117568				[illegible]	[illegible]	BOLT-SD..250-28X.875,D	[illegible]
	1	1		2117571		[illegible] 33		[illegible]	[illegible]	MANIFOLD-PR NO3 BRG RT	[illegible]
	1	1		2117582				[illegible]	[illegible]	ADAPTER-STRAIGHT,1.062	[illegible]
	1	1		2117585				[illegible]	[illegible]	ADAPTER-STRAIGHT,.875-	[illegible]
	1	1		2117928		[illegible]		[illegible]	[illegible]	SEAL 257948	[illegible]
	1	1		2117967	A	[illegible] 47		[illegible]	[illegible]	RING-POSITIONING,CPR 5	[illegible]
	~~1~~			~~[illegible]~~						~~BOLT-MACH.,.250-28X1.25~~	—
	1	—	—	2118305		[illegible] AKY1461			—	SHLD AKY1461 261084	—
	1	—	—	2118306		AKY1462			—	SHLD AKY1462 261084	—
	1	—	N/S	2118576					—	PUMP 258311	—
	1	—	N/S	2119425					—	SEAL+SUPPORT ASY-NO 3	—

SOURCE OF REPLACEMENT OR "ADD" PARTS | DISPOSITION OF REPLACED OR "CANCEL" PARTS | PAGE NO 2 OF 11

TYPE OF REQUISITION OR SUPPLEMENT: ADD & CANCEL | ORIGINAL PULL | SHORTAGE ON PREVIOUS PULL | REPLACE "LOST" PART | REPLACE USED PART | ENGRG. CHG. OR EXP. RELEASE | No. F 40257

PWA F [illegible] REV 6/57

SPEC CHECK

Figure 3. Experimental Parts Requisition or Supplement FIIE

The data are then processed into the engine or rig parts history decks. One deck is maintained for each rig and engine, consisting of IBM cards (figure 4) arranged in sequence by part number and by part name within each engine section. The deck is checked for accuracy in the Reliability Data Center and tabulated for distribution to Experimental Engineering. These tabulations are supplied for the end of an assembly, for any test changes, for the end of a test, for any cancelled parts, and if overages and shortages of the part occur.

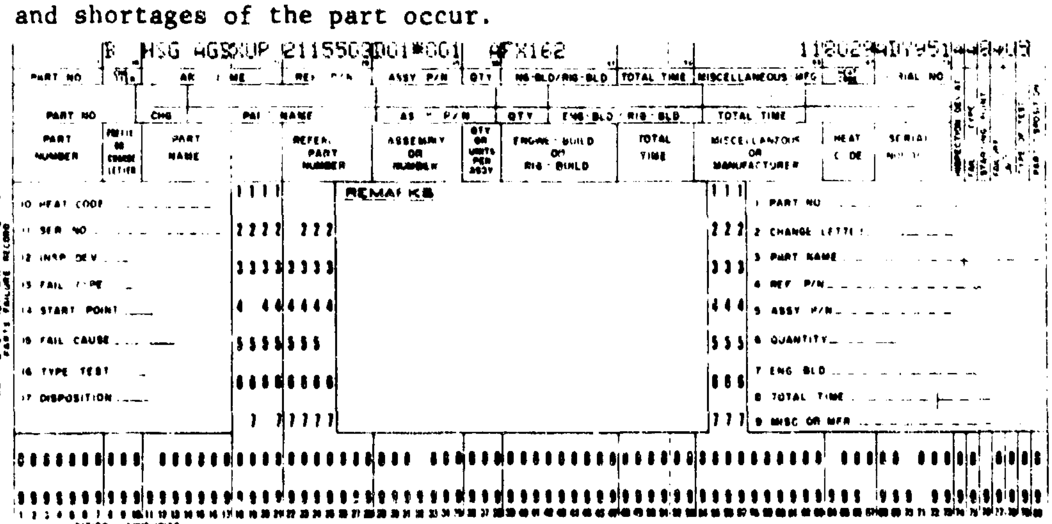


Figure 4. IBM Card Used in Engine or Rig Parts History Decks FIIE

When a change is to be made to a rig or engine to either replace parts or exchange them between engines, the Experimental Engineer forwards a copy of the Experimental Parts Requisition to the Reliability Coordinator. A report listing the date and the time accumulated on the engine or rig prior to the change is included. This information is keypunched in the Reliability Data Center and the engine deck is updated on an IBM 360 computer. The computer program adds the new parts and cancels the parts which are replaced. In addition, the accumulated time on all parts for this engine or rig is brought up to date.

At the end of a test the deck is updated by adding the final run time. Then the total history of this engine or rig is stored in computer memory. From this source any period of engine history can be reconstructed.

The most important output from this system are the parts surveys for reliability mortality distribution analysis. Part surveys are computer tabulations that list total engine test time on any serialized part or total engine test time on any set of similar parts and the corresponding history of engine and rigs. They may be extended to include special summaries of accumulated test times of all parts in specific engine zones or sections. These parts surveys form the basis of an information retrieval system for accumulated time on critical engine parts. Surveys may be requested by any engineer.

As a byproduct of the parts history system, two engineering records are produced by computer tabulation:

1. Add and Cancel Summary (figure 5) which lists all the changes made to an engine build

2. Engine Historical Record-Parts List (figure 6) which lists all parts currently in the engine with the quantity of each part, the seri l numbers and accumulated time, and other relevant data.

PRATT & WHITNEY AIRCRAFT
FLORIDA RESEARCH AND DEVELOPMENT CENTER
PWA F-128-F
REVISED APRIL 1, 1965

ENGINE HISTORICAL RECORD — PARTS LIST

DATE 4/02/66 ENGINE TYPE TEST CHANCE ENGINE NO. FX161 BUILD 1A PAGE 1

	PART NO	PART NO SUFFIX	CHANGE LETTER	PART NAME	SERIAL NO		ASSEMBLY NO		TOTAL TIME		
			JPE	E.KRENEK							
			EE	R.ANDERSEN							
			EE	R.BURSEY							
			EE	D.MILLER							
	TEST	STAND		AREA 34							
	TEST	TYPE		INITIAL RUN						FX161 .1A	
										FX161 .1A	
				APRIL 2.66			END	OH	4.58	FX161 .1	
				MARCH 31.66			START	OH		FX161 .1	
							NET	OH	4.58	FX161 .1	
				ADD							
A	500539			BRG OPT	4		2118029	437361			
A	2043811		A	BRG	262	4	2115502	437360			D02*
A	2043811		A	BRG	272	4	2115502	437360			D03
A	2073173			BRG	35		2118029	437362			D03*
A	2118030			GEARSH 33	ADL626		2118029	437362			D04*
A	2115503		B	HSG AGBXUP	ADW874		2118029	437362			D07*
A	2095083		C	SEAL	ABN431		2118029	437350			D10*
A	2118037			SEAT SLNG	UNK		2118029	437362			D13*
											D14*001
				CANCEL							
A	500539			BRG OPT	5		2118029	F39022	4.58		D02*001
A	2043811			BRG	277		2118029	437360	4.58		D03
A	2043811			BRG	267		2118029	437360	4.58		D03*
A	2073173		A	BRG OPT	42	6	2118029	F32287	4.58		D04*
A	2118030		C	GEARSH 33	ADY625	4	2118029	431057	4.58		D07*
A	2115503		B	HSG AGBXUP	ADW875	9	2118029	F32296	4.58		D10*001
A	2095083		C	SEAL	ADN428		2118029	F39022	4.58		D13*
A	2118037			SEAT SLNG	UNK	2	2118029	424023	4.58		D14*001

Figure 5. Add and Cancel Summary

PRATT & WHITNEY AIRCRAFT
FLORIDA RESEARCH AND DEVELOPMENT CENTER
PWA F-128-F
REVISED APRIL 1, 1965

ENGINE HISTORICAL RECORD — PARTS LIST

FIIE

DATE 6/14/66 ENGINE TYPE END OF ASSY ENGINE NO. FX161 BUILD 3 PAGE 1

	PART NO	PART NO. SUFFIX	CHANGE LETTER	PART NAME	SERIAL NO.		ASSEMBLY NO.		TOTAL TIME	
			JPE	E. KRENEK						
			EE	R.ANDERSEN						
			EE	R. BURSEY						
			EE	S. JONES						
			EE	D. MILLER						
5	2116282		B	CASE DBFR	AAM784	2	2119999	445331	13.76	
5	2115290		B	CASE DBRR	UNK	6	2119999	F32329	13.76	1*001
5	2116165		E	CASE DIFDR	AAM780	6	2119999	F32327 .45	13.76	3*001
5	2119947			CHAMBER DYH	ADS646	7	2119999	426948 .45	13.76	4*001
5	2119980			DEFLECT CC	QTY030	6	2119999	441714 .45	13.76	5*001
5	2115675	AKY2605		DEFLECT CC	QTY060	2	2119999	431793	2.08	6*030
5	2115552		C	DUCT SETDIF	UNK	4	2119999	430852 .45	13.76	7*060
5	2115528		F	DUCT FEX	UNK	6	2120000	F32409 .45	13.76	8*001
5	2117777	AKY1046		DUCT HTINFR	ADY229	4	2119999	427127 .45	13.76	9*001
5	2117763			DUCT HTINRR	ADY356	5	2119999	422528 .45	13.76	10*001
5	2115664	L213260		LINER DBFR	QTY060	6	2119999	445413 .45	13.76	11*001
5	2115689	AKY2542		LINER DBITM	QTY060	3	2119999	432255 .45	13.76	12*060
5	211569	AKY2540		LINER DBRR	QTY060		2119999	432255 .45	13.76	13*060
5	2115125			NOZ DB	UNK	6	2119999	424473 .45	13.76	14*060
5	2115937			NOZ FZNI	ADY852		2119999	441690	13.76	15*001
5	2115990			NOZ FZNI	ADY844		2119999	441690	13.76	16 001
5	2115990			NOZ FZNI	ADY841		2119999	441690	13.76	17 001
5	2115990			NOZ FZNI	ADY840		2119999	441690	13.76	17 002
5	2115990			NOZ FZNI	ADY842		2119999	441690	13.76	17 003
5	2115990			NOZ FZNI	ADY838		2119999	441690	13.76	17 004
5	2115990			NOZ FZNI	ADY839		2119999	441690	13.76	17 005
5	2115990			NOZ FZNI	ADY843		2119999	441690	13.76	17 006
5	2115990			NOZ FZNI	ADY845		2119999	441690	13.76	17 007
5	2115990			NOZ FZNI	ADW042		2119999	441690	13.76	17 008
5	2115986			NOZ FZNI	ADZ148		2119999	441690	13.76	17 009
5	2115986	AKY2106		NOZ FZNI	ADY361	4	2119999	430852	13.76	17*010
5	2115986	AKY2106		NOZ FZNI	ADY359	4	2119999	430852 .45	13.76	18 001
5	2115786			NOZ FZNI	ADY853		2119999	441690 .45	13.76	18 002
5	2115986			NOZ FZNI	ADY854		2119999	441690	13.76	18 003
5	2115986			NOZ FZNI	ADY857		2119999	441690	13.78	18 004
5	2115986			NOZ FZNI	ADZ149		2119999	441690	13.76	18 005
5	2115986			NOZ FZNI	ADZ147		2119999	441690	13.76	18 006
5	2115986	AKY2106		NOZ FZNI	ADY358	4	2119999	430852	13.76	18*007
5	2115986	AKY2106		NOZ FZNI	ADY362	4	2119999	430852 .45	13.76	19 001
5	2115986	AKY2106		NOZ FZNI	ADY360	4	2119999	430852 .45	13.76	19 002
								.45	13.76	19*00

Figure 6. Engine Historical Record - Parts List

FIIE

SECTION III
QUALITY ASSURANCE PROGRAM

A. OBJECTIVE

The overall objective of the Quality Assurance Program is to assure the quality required for a safe, dependable, and economical airline SST engine. To accomplish this, the program provides for meeting the specific objectives of establishing quality requirements, assuring compliance with technical and quality requirements, and providing feedback of information to improve quality procedures and standards. The program utilizes the concepts and principles used to develop engine dependability on current P&WA commercial turbine engine programs.

The program will satisfy the requirements of such government quality specifications as MIL-Q-9858A and NPC-200-2.

B. POLICIES

The Quality Assurance Program is based on the Pratt & Whitney Aircraft Quality Control Manual and supplemental Quality Procedures. The former establishes the basic policies and the latter describe the procedures required to conform to the policies. Because quality assurance policies apply throughout the Pratt & Whitney Aircraft Division, the same policies will be applied to the JTF17 engine that have been applied to the J58, the JT3D, the JT8D, and the other current engines.

The portion of the quality program described herein for prototype and production engines is applicable to both the Florida Research and Development Center and the Connecticut operations of Pratt & Whitney Aircraft.

C. ORGANIZATION

The quality assurance aspects of the JTF17 engine program will be monitored for the Program Manager by the JTF17 Product Assurance Manager, who may request special reports or corrective action from the Chief of Quality Assurance (FRDC) or the Quality Manager (Connecticut operations) as applicable.

The Chief of Quality Assurance at the FRDC will direct all phases of the quality control program, except for the Materials Control Laboratory functions, during the development and prototype phase of the SST Engine Development Program. He is responsible for the following sections:

1. Quality Engineering
2. Experimental Inspection
3. Delivery Inspection
4. Quality Review.

The Quality Manager at the Connecticut operations will direct all phases of the Quality Control Program, except for Material Control Laboratory functions, during the production engine phase of the SST Engine Delivery Program. He is responsible for the following sections:

1. Quality Engineering
2. Inspection
3. Quality Review

The basic responsibilities of the major subsections of the FRDC Quality Assurance organization are shown in figure 1. Included is the responsibility for transmitting to the Connecticut quality control organization the experience gained and the quality requirements established during the development and prototype phases of the program.

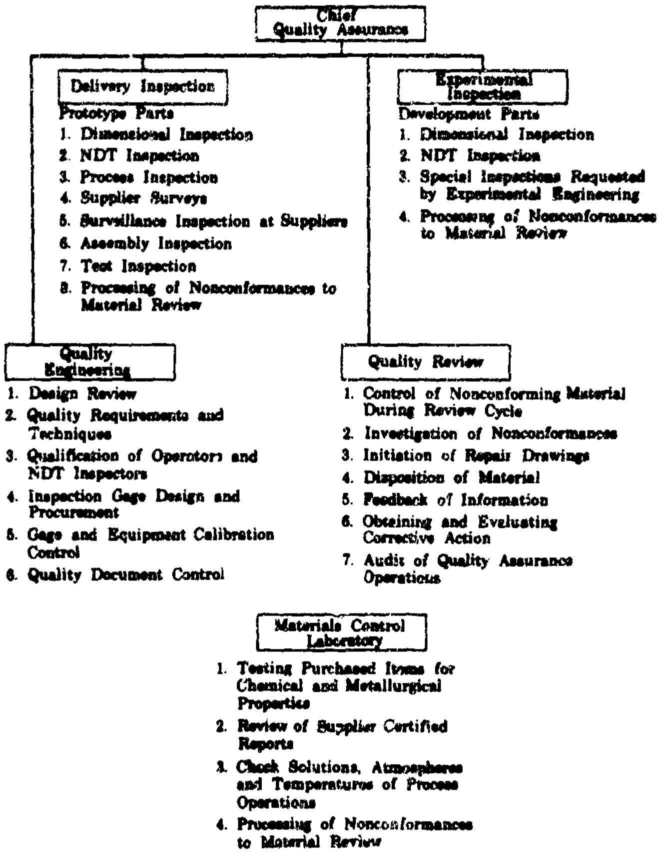


Figure 1. Quality Assurance Responsibilities FD 17565 FIII

Figure 2 shows in chart form the quality assurance organization for Pratt & Whitney Aircraft's Florida Research and Development Center.

Pratt & Whitney Aircraft's JTF17 program management organization is described in Volume V, Report I.

Figure 3 shows the quality control organization for Pratt & Whitney Aircraft's Connecticut operations.

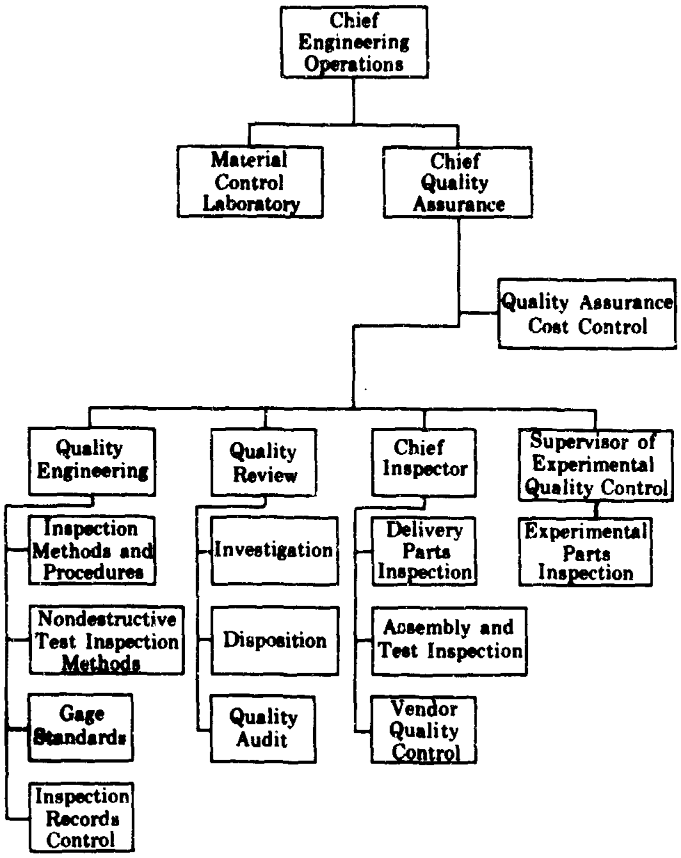


Figure 2. Quality Assurance Organization - FRDC FD 16466 FIII

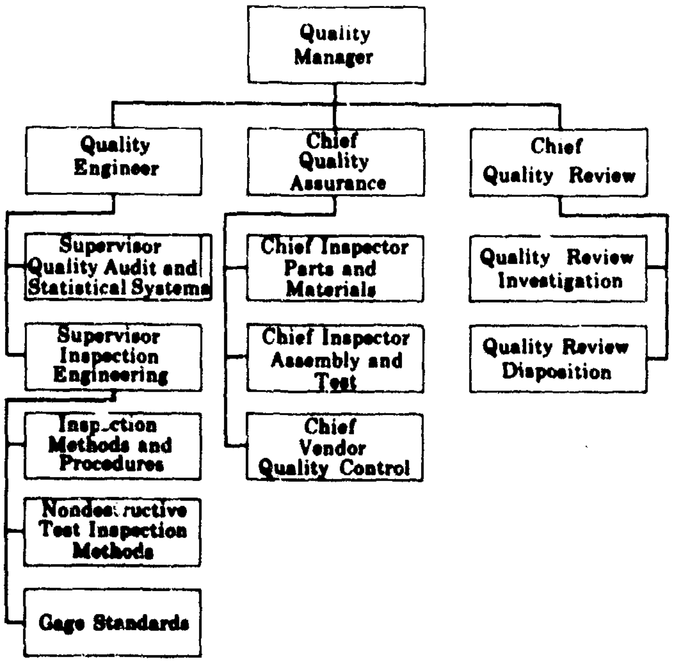


Figure 3. Quality Organization - East Hartford FD 17564 FIII

D. GENERAL

1. Major Features

The major tasks of the Quality Assurance Program in assuring compliance to the technical and drawing requirements for materials, parts, and assemblies are to:

1. Establish nondestructive test requirements, acceptance standards, inspection techniques and methods, and assembly and test inspection requirements.
2. Survey suppliers for adequacy of their quality control systems and assure transmittal of all quality requirements to the supplier.
3. Provide laboratory control to assure conformance to material requirements and chemical and metallurgical processing requirements of parts and assemblies.
4. Assure availability of trained and certified personnel for those types of inspection requiring special training and certification.
5. Determine inspection facilities and tooling needed and assure availability.
6. Document nonconformances found during inspection, evaluate nonconformances for usability, determine corrective action for defect prevention, and feedback information for possible design change.
7. Determine the problem areas that involve special inspection techniques or equipment and provide solutions.

2. Time-Phased Requirements

The time-phased requirements of the Quality Assurance Program include the preparation of the documents and the procuring of the special tooling required for the inspection of parts and assemblies during the manufacturing, assembly, and test phases. The time schedule for the completion of the documents and special tooling by major engine subsection is shown in figure 4.

The documents to which time-phasing applies are:

1. Quality Assurance Data Sheets (QADS) - QADS summarize the nondestructive test inspection requirements and special quality requirements that apply to each part or assembly.
2. Inspection Method Sheets (IMS) - IMS detail instructions for the complete inspection of a purchased or fabricated part or assembly.
3. Engine History Record Sheet (EHRS) - EHRS detail instructions and records of the complete inspection of a nonmachined assembly.

Special inspection tooling consists of single-purpose, designed gages and fixtures used to inspect parts and assemblies.

Quality Assurance supervision hold weekly meetings to review parts status, problems, and solutions to assure that scheduled requirements are met.

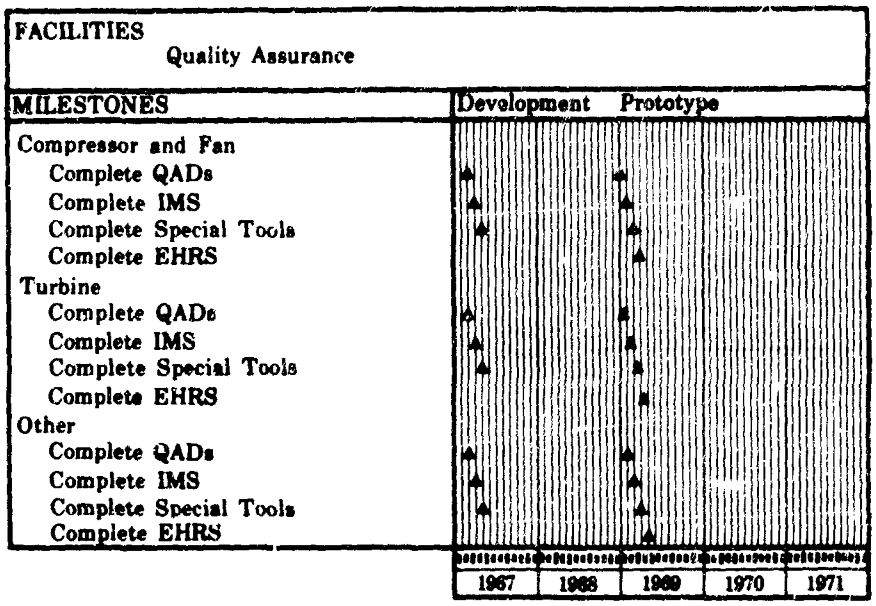


Figure 4. Quality Assurance Milestone Chart FD 17566 FIII

3. Key Elements

Key elements for implementation of the Quality Assurance Program are:

1. Facilities - The major portion of the present quality assurance facilities will be adequate for the development work in Phase III. Prototype engine build will require some duplication of existing equipment because of the increased number of parts. Present floor space of 28,000 square feet will be increased by 3000 square feet for development and by an additional 11,800 square feet for the prototype delivery and overhaul portion of the Phase III program.
2. Personnel - The quality assurance organization, consisting of 254 people, will be increased by 25 people during development and by an additional 130 people for the prototype and overhaul portion of the Phase III program. The increase will be accomplished over a period of 2 years.
3. Training - Training courses from previous programs are available to train replacement and additional personnel in such special skills as ultrasonic inspection, eddy current inspection and fluorescent penetrant inspection.
4. The quality program requirements for the Phase IV development and Phase V production follow-on portions of the contract, to be performed at FRDC and the Connecticut operations respectively, will be adequately staffed and equipped with existing personnel and facilities at the time those phases are implemented.

E. DESIGN AND DEVELOPMENT CONTROLS

1. Drawing and Specification Review

The system for drawing and specification review prior to release for fabrication consists of:

1. Engineering design review
2. Design metallurgy review
3. Project engineering review
4. Quality assurance review.

a. Engineering Design Review

A design analyst analyzes and checks design layouts, engineering drawings, and revisions to engineering drawings. He is responsible for:

1. Checking that the design contains all features necessary for proper function.
2. Checking for dimensional accuracy and completeness and clarity of notes and dimensions. This part of the review also covers checking for proper fit with mating parts; reasonable tolerance selection; freedom from unnecessary duplication of dimensions; adequate allowances for shrinkage, distortion, and machining; avoidance of excessive tolerance accumulation; and provision for concentricity and squareness control.
3. Assuring that the design permits the most simple and efficient fabrication methods possible.
4. Checking for proper application of company and government standards and the correct listing of specifications.
5. Parts selection that uses a maximum of standard parts.
6. Overall review to assure consistency of drafting practice in the use of notes and presentation of views with respect to similar parts.

b. Design Metallurgy Review

The design metallurgy group, which is an integral part of the Design Department, performs the following specifications review:

1. Reviews all design layouts and revisions for correct material and processing specifications.
2. Reviews all drawings involving welding, brazing, heat treating, hard facing, and diffusion coating.
3. Initiates and follows up preparation and revision to material and process specifications.

c. Project Engineering Review

The cognizant project engineer reviews and approves each new drawing release or engineering change to assure that it satisfies the requirements for configuration and functional characteristics resulting from test experience.

d. Quality Assurance Review

Quality Assurance personnel review all drawings for inspectability and quality requirements prior to release. This review continues during subsequent quality assurance document preparation throughout the planning cycle. Feedback of engineering change requests to the Design Department occurs throughout the planning cycle.

2. Quality Document Preparation

a. Quality Assurance Data Sheets

Nondestructive Test Inspection Methods personnel review each new or changed drawing for characteristics of design, material specifications, and process specifications that will necessitate use of nondestructive test methods of inspection for assurance of quality. This review is also the basis for determining if special quality control requirements, such as permanent traceability through the use of serial numbers and heat identification, shall apply. The review may show a need for refining an existing method, developing a new method, or establishing a new quality standard.

The preparation of the quality assurance data sheet consists of listing applicable:

1. Quality requirements, such as radiographic or sonic, and the location in the fabrication sequence
2. Methods specifications
3. Quality standards.

b. Methods Specification

Methods specifications are the detailed instructions prepared by the nondestructive test inspection methods group to describe the techniques the inspector must follow to perform radiographic, fluorescent penetrant, magnetic particle, sonic, surface temper, etch, grain size, and eddy current inspection. The methods specification is specified on the Quality Assurance Data Sheet and the Inspection Methods Sheet.

The Nondestructive Test Methods group has specialists whose only responsibility is to improve existing nondestructive test inspection techniques and to develop new techniques. Examples of active projects are:

1. Hollow blade and vane wall thickness measurement
2. Use of eddy current, thermoelectric, and spectrographic equipment for alloy type testing of alloys difficult to segregate
3. Use of eddy current equipment to detect cracks in leading and trailing edges of blades and vanes
4. Automation of X-ray film reading
5. Use of superfine, high contrast X-ray film in blade and vane inspection.

c. Quality Standards (Workmanship Standards)

The Nondestructive Test Inspection Methods group develops and designates quality standards for application to specific parts. These provide inspection acceptance limits for surface and internal conditions that affect quality of material, parts, or assemblies. In some instances, a standard establishes a measurement practice when there is a probability that multiple source procurement could give different inspection results.

New and revised quality standards must be approved by Project Engineering and Design Engineering in all cases, and by the Materials Laboratories when metallurgical conditions are involved. Project Engineering and Design Engineering provide a background of stress requirements and test experience, and the Materials Control Laboratory provides a background of metallurgical requirements.

Existing standards developed from previous experience with similar parts, materials, and processes are used if they are suitable. The Nondestructive Test Inspection Methods group undertakes the development of new standards or revisions to standards when design review indicates a need or when experience is gained during the progress of the program.

Quality standards are classified and identified as shown in table 1.

Table 1. Quality Standards Classification and Identification

Class	Prefix
Radiographic	XRS
Fluorescent penetrant	FPS
Magnetic particle	MPS
Sonic	SIS
Surface finish	SFS
Visual	VIS
Surface temper	STS
Dimensional control	DCS
Etch inspection	EIS
Grain size inspection	GSS
Eddy current inspection	ECS

d. Inspection Methods Sheets

Inspection Methods personnel prepare inspection methods sheets for use in the inspection of purchased and shop-fabricated parts and assemblies. These sheets establish the inspections necessary to cover the requirements of the quality assurance data sheet, the engineering drawing, and referenced specifications.

The inspection methods sheet is a complete listing of inspection requirements for the part or assembly and it includes:

1. The particular inspection department that is to perform each inspection
2. The sequence during the fabrication for performance of major inspection operations

3. Process operation procedures to be verified during the processing operation for Pratt & Whitney Aircraft manufactured parts
4. The nondestructive test inspection required, with the method specification and standard to be used
5. Applicable quality standards
6. Hidden dimension control requirements for procured parts
7. Each dimensional characteristic to be inspected and the gages to be used
8. Any approved application of statistical sampling
9. Identification requirements
10. Routing destination for accepted items.

e. Engine History Record Sheets

The engine history record sheets are detailed instructions for the inspection of the engine assembly and establish the inspection necessary to assure compliance with all engineering requirements related to the assembly operation. The engineering criteria for which the engine history record sheets provide coverage are assembly drawings, clearance charts, and special specifications that the project engineer prepares and publishes as engineering instructions. The engine history record sheets provide the inspector with a means for documenting the completion of each inspection operation and any action that becomes necessary for acceptance. The record thus provided becomes a part of the permanent build records for each engine.

f. Quality Procedures

Quality procedures provide a uniform method of detailing the responsibilities and activities of all groups within Quality Assurance Department. They are written to amplify all the quality objectives and policies, to assure objective and policy implementation, to establish the responsibilities and duties of each subsection of Quality Assurance, and to list the step-by-step operation to accomplish the requirement.

Inspection Methods prepares and distributes quality procedures. Each new or revised procedure must have the approval of the Chief of Quality Assurance, the Quality Engineer, and the cognizant section chief before release for use.

Quality procedures are classed in six types for easy association with quality control functions, as follows:

1. Quality assurance procedures that are of concern to all sections. An example is the preparation of labor distribution cards.
2. Quality engineering procedures that apply to the operations of quality engineering subsections. Examples are the preparation of inspection method sheets and the calibration of inspection equipment.
3. Quality inspection procedures that relate to inspection operations that are the responsibility of the Chief Inspector. Examples are raw material inspection and assembly inspection.

4. Quality review procedures that are procedures for control and disposition of nonconforming items. Examples are quality review investigation, parts and material returned to vendor, and general quality review procedure.
5. Quality test procedures that apply to the operations of test inspection. Examples are component test inspection and instrument calibration surveillance.
6. Experimental quality control procedures that apply to the dimensional inspection requirements of development parts. Examples are turbine blade and vane experimental inspection and the specification check of development engines and rigs.

3. Qualification Test

Throughout the development cycle and prior to the delivery of ground test engines, tests are performed to demonstrate the capability of the part or assembly to meet established requirements. These tests are contractual requirements and are listed as major milestones in the development phase. Quality Assurance has the responsibility to:

1. Provide inspection of detail parts and assemblies to assure that the part meets all design and quality requirements.
2. Provide assurance that only acceptable parts of the correct part number and change letter configuration are used in the test.

4. Producibility

Producibility is discussed in detail in Volume V, Report G. Producibility evaluation occurs during all phases of the quality assurance program. All subsections of Inspection Methods are required as a part of their producibility function to request an engineering change if during the design review or preparation of quality assurance data sheets, method specifications, inspection method sheets, and engine history record sheets, they find that an engineering requirement cannot be inspected or controlled.

Quality Review personnel request an engineering change if they find while investigating a nonconformance that a change will eliminate or reduce the probability of recurrence.

F. CONTROL OF CONTRACTOR PROCURED MATERIAL, PARTS, AND ASSEMBLIES

1. Selection of Procurement Sources

The Purchasing Department investigates a potential supplier's facilities to determine the ability to perform the operations to produce the type of part or assemblies to be procured. Quality Assurance performs surveys to ascertain the potential supplier's ability to produce quality products that will meet all the technical and quality requirements and to determine that a quality system is in operation to assure that these requirements are met. Project Engineering, on special parts and assemblies, requires engineering source approval for a supplier when functional requirements and/or qualification tests indicate that supplier selection should be controlled.

a. Vendor Surveys

A quality control representative from the Vendor Quality Control subsection of Quality Assurance surveys the facilities of each company that Purchasing wishes to establish as a supplier. To satisfy P&WA requirements for a quality program, a supplier must be able to meet the applicable requirements of Quali· Specification PWA-QA-6064 or PWA-OA-6068. Specification PWA-QA-6064 applies when fabrication will be to a P&WA design, and Specification PWA-QA-6068 applies when part design is the supplier's responsibility. Upon completion of a survey, the quality control representative reports his findings, including his recommendations concerning changes to the supplier's system to meet P&WA quality requirements. Purchasing and Quality Assurance supervision determine whether the company should be added to the list of approved suppliers.

b. Engineering Source Approval

Engineering indicates this requirement by a special note on the drawing for each part or assembly to which it applies. An engineering source approval data sheet for the part number provides Purchasing and Quality Assurance with the names of approved suppliers and the reasons for exercise of this control. An important feature of this system is that a supplier is not permitted to make changes in his processing or fabrication techniques without prior P&WA engineering approval.

2. Procurement Documents

a. Basic Technical Requirement

The basic documents containing technical and quality requirements that the purchase order transmits to a supplier are:

1. Assembly and/or detail drawings
2. Material specifications (for metallurgical and chemical requirements)
3. Process specification (for heat-treat, plating, or coatings)
4. Method specification (for inspection techniques)
5. Quality standards (for acceptable limits)
6. Purchase performance specifications (for component functional testing)
7. Specification PWA 300 (for chemical and metallurgical testing and certification of performance and results).

b. Contractor Source Inspection

The Vendor Quality Control Group of Quality Assurance reviews each purchase order to determine if the part or assembly being procured will require source inspection. This determination is based on the part complexity because of manufacturing techniques, dimensional requirements, or assemblies consisting of multiple details; hidden dimension requirements; the availability of a vendor quality control representative at the supplier's plant; or the proprietary nature (vendor design) of the part. If determined necessary, an appropriate block on the purchase order indicates

the requirement. This information is used by Vendor Quality Control to establish source inspection at a vendor's plant, or if source inspection already exists, to notify the source inspector of the requirement. Receiving inspection uses the information from the purchase order to assure that proper documentation is received with the lot of material.

c. Subcontractor Quality Program

The purchase order defines the requirements for a supplier's quality program by reference to Quality Specification PWA-QA-6064 or PWA-QA-6068. The quality specification establishes the overall requirements for an effective program. (See Paragraph F.1.a above.)

d. Purchased Raw Material

Specification PWA 300 establishes the test methods required to satisfy the chemical and metallurgical requirements of the material specification and also provides for submission of a certified report covering test results.

e. Evidence of Supplier Inspection Performed

Evidence of supplier inspection is necessary when acceptance is based upon P&WA source inspection. In these instances, the quality control representative submits a report, PWA 10207, showing the inspection completed and any conditions that will require attention after receipt at P&WA. Suppliers must report, in writing prior to shipment, all nonconformances in production or prototype parts for authorization to repair or ship the nonconformance. The supplier must reference this authorization on the shipping document.

f. Identification, Preservation, and Packaging

Specification PWA 310, which each engineering drawing references, provides the supplier with complete instructions for proper identification of the article. The purchase order lists any special requirements concerning preservation and packaging, such as Specification PWA 381 for the use of shipping closures or Specification PWA 382 for items requiring special handling.

3. Purchase Order Review

An Inspection Methods representative reviews each purchase order prior to issuance to assure the inclusion of all quality requirements. The items of major importance are that:

1. The part print is current to the latest change
2. The material specification is current to the latest change
3. The latest quality assurance data sheet is attached
4. PWA 300 and PWA 310 are specified for laboratory testing and identification
5. Approved sources are specified when required for processing specifications, and nondestructive test inspection and engineering source approval.
6. Source inspection is specified if necessary.

4. Receiving Inspection

Receiving inspection of materials, parts, and assemblies consists of verification of all technical and quality requirements for each lot received. This verification will consist of a review of the documents accompanying the material or parts for source inspection results, supplier laboratory tests, and nonconformances requiring prior authorization; laboratory tests of samples of parts from each lot; dimensional inspection of parts not previously source inspected; nondestructive tests required by QADS; and final inspection prior to delivery to stores.

a. Laboratory Control

Laboratory control consists of testing the material for conformance to specification and/or drawing requirements. Materials Control Laboratory personnel select samples and perform tests in accordance with written procedures. They prepare reports from test results indicating acceptance or the existence of a nonconformance requiring Quality Review disposition.

The Materials Control Laboratory surveys major suppliers to determine if the facilities, personnel, and technical competence meet all requirements for metallurgical and chemical control. If approved, the supplier is classified as "Laboratory Controlled at Source". Results of laboratory tests performed by approved suppliers determine material acceptance. Material Control Laboratory vendor metallurgical control representatives provide surveillance of approved vendors. Material Control Laboratory personnel at receiving inspection perform periodic audi checks to assure compliance with all requirements.

b. Dimensional Inspection

All parts in each lot are dimensionally inspected in accordance with the requirements of the inspection methods sheets which list the dimensional characteristics and the gages or tooling to be used for each characteristic. Total (100%) inspection is required for each characteristic unless a statistical sampling plan is approved for the characteristic.

c. Nondestructive Test Inspection

Each part for which a nondestructive test is specified on the quality assurance data sheet and the inspection method sheet is inspected upon receipt for each test required. Each test is performed in accordance with the applicable methods specification, and the results are inspected to the requirements of the quality standard.

d. Final Inspection

Final inspection consists of verifying that all required inspections have been performed, laboratory results of the metallurgical inspection approved, and nonconformances properly cleared through Quality Review. The identification requirements for marking are established, and the parts are routed to the proper destination.

e. Flow Diagram

Figures 5 through 8 illustrate the inspection system for purchased parts and assemblies.

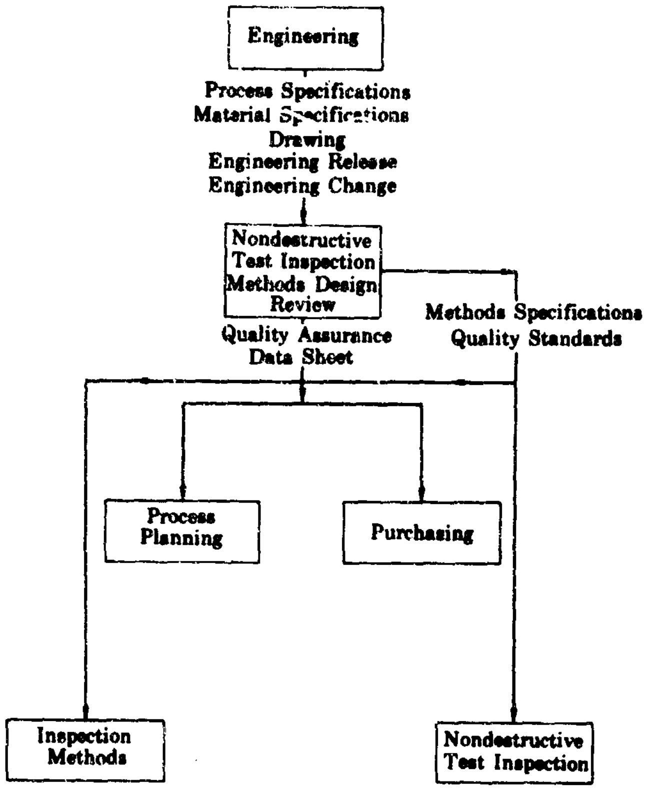


Figure 5. Design and Quality Control Document Flow

FD 16467
FIII

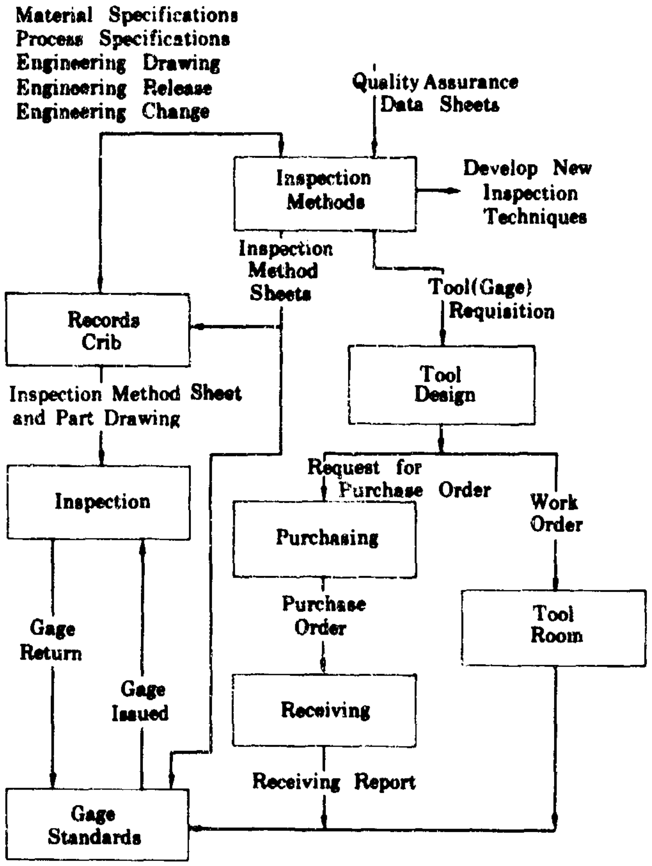


Figure 6. Design and Quality Control Document Flow (Continued)

FD 16468
FIII

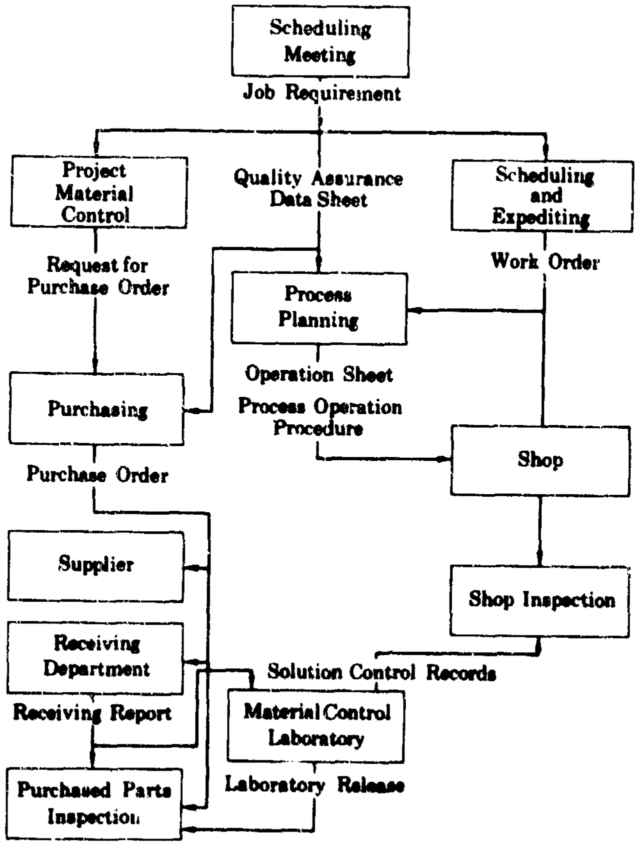


Figure 7. Procurement Document Flow

FD 16460
FIII

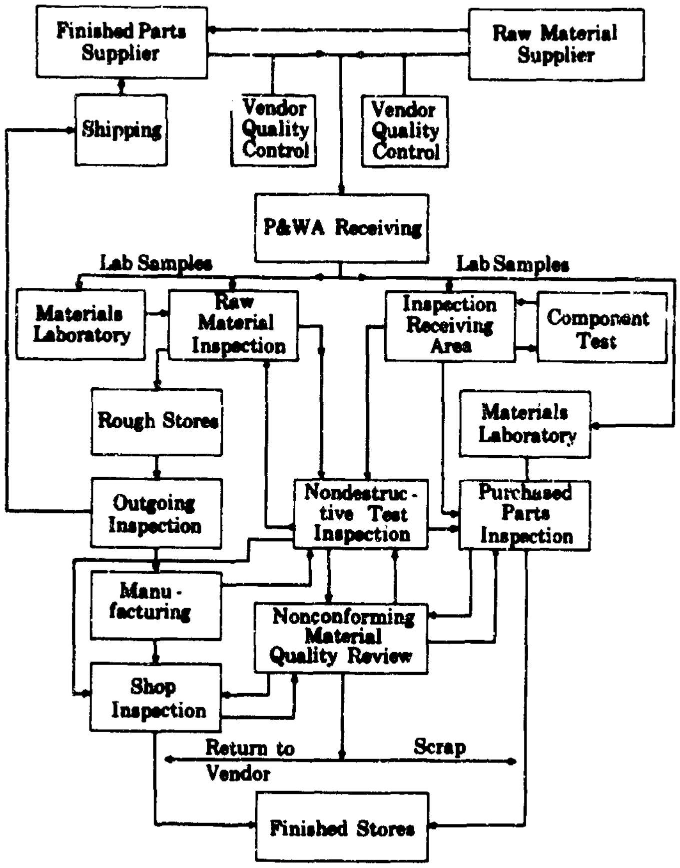


Figure 8. Material and Parts Flow

FD 16470
FIII

G. CONTROL OF CONTRACTOR-FABRICATED ARTICLES

1. Conformance Criteria

Documents containing conformance criteria by which inspection determines compliance with engineering drawings and specifications are:

1. Inspection methods sheets (See Paragraph E.2.d above)
2. Methods specifications (See Paragraph E.2.b above)
3. Quality standards (See Paragraph E.2.c above)
4. Engine history record sheets (See Paragraph E.2.e above)
5. Process operation procedures - for detailed instructions approved by Quality Assurance or the Material Control Laboratory for the control of processing parts or assemblies for plating, welding, brazing, and heat treatment
6. Material Control Laboratory manual sections G and L which list the procedures the Material Control Laboratory follows to assure control of solutions, atmosphere, temperatures, etc., that are essential for the control of metallurgical and chemical processes
7. Component calibration schedules for detailed engineering instructions listing equipment requirements, test routines, and operation limits for each component requiring functional test before assembly in the engine

8. Test instruction sheets and appendices for detailed engineering instructions listing equipment requirements, test routines, and operation limits for the complete engine.

2. Inspection and Test Planning

a. Inspection Procedures

Figure 9 and Paragraphs C, E.2, and G.1 above show delegation and purpose of the planning functions and quality control documents. Figures 5 through 9 outline the complete inspection operation.

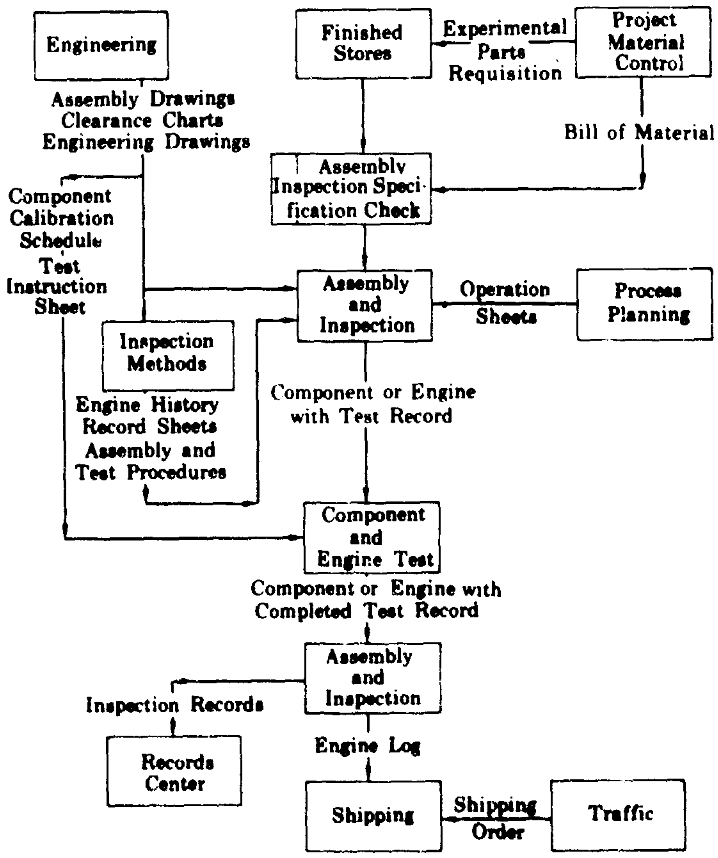


Figure 9. Assembly and Test Document and Material Flow (Prototype and Production) FD 16471 FIII

b. Workmanship Standards

See Paragraph E.2.c above.

c. In-Process Inspection

The inspection methods sheet for a part or assembly provides necessary in-process inspection (see paragraph E.2.d above). When preparing the inspection methods sheet, the inspection methods planner arranges with the process planner preparing the manufacturing operation sheet to show the necessary inspection at the proper location in the fabricating sequence.

d. Assembly Inspection

Assembly Inspection functions include the following:

1. A specification check of all details delivered to the assembly area to assure the correct part number and change letter in accordance with the bill of material

2. Witnessing all subassembly and final assembly operations of all components and complete engines from green build through final packing in accordance with the requirements of the engine history record sheets, and documenting each inspection operation of the engine history record sheets for the permanent build records.

e. Test Inspection

The test inspector performs his duties and documents results as detailed in the quality test procedures. Component calibration schedules and test instruction sheets supply the inspection conformance criteria. The test inspector's duties include:

1. Witnessing all component bench tests and engine tests
2. Checking that all instruments have a current calibration
3. Initiating a request for engineering acceptance to obtain project engineering recommended action for any nonconformance
4. Signing test data sheets indicating acceptance.

3. Fabrication Controls

a. Production Tooling and Fabrication Equipment

The Tool Inspection section of the Master Mechanic's operation performs initial inspection and periodic reinspection for all fabrication tooling. To assure the accuracy of this inspection, the Gage Standards group of Quality Engineering performs the initial and periodic reinspection of all measuring devices assigned to Tool Inspection. In addition, if a tool is one upon which inspection bases acceptance of a characteristic, Gage Standards requires Tool Inspection to prepare a written report on the condition of the tool after each inspection. If the report indicates a need for repair or replacement, Gage Standards is responsible for notifying inspection supervision to take appropriate action.

b. Material Control

The engineering drawing and Specification PWA 310 establish the identification system for materials, parts, and assemblies. The drawing establishes the location where marking is permitted and specifies the method. Specification PWA 310 describes the required identification for bar stock, sheet stock, tubing, castings, forgings, parts, and assemblies and also describes recognized methods for marking with restrictions applicable to use.

Inspection checks all raw material before release from stores for fabrication to determine that the identification shows the material to be that required for fabrication of the part number involved. The work order stays with each lot until delivery to finished stores and carries serial numbers and heat identification (if applicable) to assure availability to the marker at the proper time. Manufacturing operation sheets stipulate the time for final marking, if permitted, and the method. Inspection method sheets for the part provide for inspection to see that all required identification is on the part or container.

c. Control Cleanliness

The following documents establish cleanliness requirements:

1. Process operation procedures for shop and assembly operations
2. Assembly and test procedures for assembly and test operations
3. Quality procedures for inspection operations
4. Engineering instructions for assembly and test where special engineering requirements apply
5. The Materials Control Laboratory Manual when laboratory testing is necessary for materials and solutions
6. Inspection methods sheets, engine history record sheets, manufacturing operations sheets, or assembly operation sheets that reference the above documents when applicable.

d. Process Control

This topic is discussed in Paragraphs E.2.d, G.1, G.2.c, and F.4.a.

e. Change Control

There is a change control system for each document affecting the quality control operation. Quality procedures establish the responsibility for distribution and receipt of each document. Following is a list of the documents with the corresponding change identification system:

1. Engineering drawings - part number and change letter with suffix numbers
2. Material specifications - specification number and change letter
3. Process specifications - specification number and change letter
4. Quality assurance data sheets - part number corresponding to engineering drawing and a control number
5. Quality standards - letter abbreviation with suffix number and change letter
6. Inspection methods sheets - part number and change letter of applicable engineering drawing and the inspection method sheet revision date
7. Engine history record sheets - numerical coding system with revision date
8. Quality procedures - Arabic numeral numbering system with letter and number suffixes and revision date
9. Engineering instructions - numerical series and change letter with revision date

10. Component calibration schedules - letters and number series with change letters and revision date
11. Test instruction sheets - numerical series with change letters and revision date
12. Process operation procedures - letters "POP" with numerical suffixes and revision date.

H. NONCONFORMING MATERIAL

1. Control of Nonconforming Material

Parts and assemblies with lists of nonconforming dimensions or requirements are received in the restricted, controlled Quality Review area. Within this area, Quality Review personnel segregate the parts by disposition, such as acceptance, repair, return to supplier, or scrap.

2. Review of Nonconforming Material

Quality Review personnel conduct a review of the nonconformance that includes an engineering investigation of the structural requirements of the part, a metallurgical investigation, and an investigation of the quality history to check for recurrence. Reinspections and additional inspection may be requested at this time to obtain information needed for the final disposition. Material review dispositions for development parts and assemblies are the responsibility of engineering personnel. Prototype and production part and assembly dispositions are the responsibility of the Quality Review personnel. Dispositions of metallurgical and chemical nonconformances are the responsibility of Metallurgical Engineering. All personnel have been qualified by training and experience in jet engine manufacture. They have access to all engineering and manufacturing personnel for specialized information or assistance. Disposition is acceptance, repair, rework to drawing, return to supplier, or rejection.

Results of the review may require changes in design or the preparation of workmanship standards to eliminate particular problems causing nonconformances.

Quality Review originates special repair drawings to describe the repair on prototype or production material when the repair is too complex for adequate written description. Quality Review coordinates the drawings with Design, Project Engineering, and Field Service. Repair drawing use must be specifically authorized in a quality review order disposition. An assigned engineer authorizes any repair to development material.

Quality Review authorization requests by suppliers for permission to repair or ship the nonconformances found during the suppliers inspection are reviewed, and if the request is satisfactory, approval is given. The authorization to ship the parts does not signify acceptance of the nonconformance. Upon receipt of the material at receiving inspection, a Quality Review order is initiated and the parts are submitted to Quality Review for the final disposition.

Appropriate symbols identify all accepted nonconforming parts or assemblies prior to delivery to finished stores to provide traceability. Quality Review mutilates or identifies parts dispositioned "Reject" to preclude future use.

I. INSPECTION MEASURING AND TEST EQUIPMENT

The selection and evaluation of measuring and test equipment is a function of:

1. The Materials Control Laboratory, for equipment to perform chemical and metallurgical testing
2. Inspection Methods, for gages and equipment to perform dimensional and nondestructive test inspection
3. The Instrumentation Laboratory, for component and engine test instrumentation.

Gage Standards inspects and approves all new inspection gages and equipment. The Instrumentation Laboratory does the same for new component engine test equipment. Each of these groups operates a call-in system to provide for reinspection or recalibration at scheduled intervals. Written instructions provide Gage Inspectors and calibration technicians with the exact method for performing the inspection or calibration. The record for each item provides space for the employee performing the work to record the results, his name, and the date of completion. In addition, the employee identifies the item with a sticker showing the date for the next scheduled recheck.

Whenever the state of the art permits, known standards provide the basis for determining accuracy of gages and equipment. Periodic recalibration and traceability to the National Bureau of Standards is a responsibility of Gage Standards and the Instrumention Laboratory for all standards under their control.

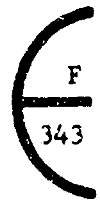
J. INSPECTION STAMPS

The design of all stamps permits identification of the employee to whom assigned. The Gage Standards Department controls, assigns, and issues various stamps to Quality Review and Inspection personnel. A card record for each stamp issued shows the individual to whom it was assigned.

The Inspection Department uses a variety of inspection stamps to indicate acceptance at various stages during the processing and fabrication of parts. The description of each stamp appears in a quality procedure that establishes the purpose. Completely inspected parts or assemblies are identified with a final acceptance inspection stamp if marking is permitted by the part drawing. Otherwise, acceptance identification is by marking the part container and accompanying documents. The final acceptance stamps are illustrated on the following page.

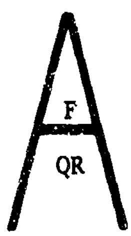
PROTOTYPE AND PRODUCTION

EXPERIMENTAL



Quality Review uses a variety of acceptance stamps to indicate acceptance of nonconforming conditions at various stages of the fabricating and processing operations. The description of these stamps appears in a quality procedure that establishes the purpose. In all cases, final quality review acceptance of a part or assembly requires identification with the final acceptance quality review stamp if marking is permitted by the part drawing. Otherwise, acceptance identification is placed on the part container and accompanying documents. The final acceptance quality review stamps are illustrat below.

PRODUCTION



PROTOTYPE

K. PRESERVATION, PACKAGING, HANDLING, STORAGE, AND SHIPPING

Engineering establishes the requirements that must be met in the preservation, packaging, handling, and shipping of parts, assemblies, and engines. These requirements are a part of operation sheets, inspection methods sheets, engine history records sheets, process operation procedures, and procurement documents. The documents that establish these operations are:

1. "P" series preservation and packaging part drawings
2. Specification PWA 354 for age control of synthetic rubber parts
3. Specification PWA 381 for use of shipping closures
4. Specification PWA 382 for handling items requiring special protection

5. Component calibration schedules when cleaning procedures are required as part of the test procedure
6. Specification PWA 311 for identification marking of spare parts packages.

L. STATISTICAL PLANNING, ANALYSIS, AND QUALITY CONTROL

The determination of statistical methods suitable for application to parts inspection is a function of Quality Engineering. This group maintains a handbook that outlines in detail:

1. Sampling plans that may be considered for use
2. Characteristics to which each plan is restricted
3. Periodic data analysis necessary to evaluate continuing or discontinuing the use of a sampling plan for a part or source of parts.

Quality Review utilizes statistical methods to analyze the need for corrective action and the major sources of nonconformances.

M. TRAINING AND CERTIFICATION OF PERSONNEL

Training and certification are requirements for fabrication and inspection processes when the development of individual skills is essential for successful performance. Examples of the fabrication processes that apply to turbine engines and for which training courses are available and certification systems in effect are:

1. Fusion welding
2 Resistance welding
3. Brazing.

Examples of training and certification programs applicable to inspectors are:

1. Magnetic particle inspection
2. Fluorescent penetrant inspection
3. Sonic inspection
4. Eddy current inspection
5. Radiograph interpretation
6. X-ray equipment certification.

The Training Department conducts the training courses, but the Nondestructive Test Inspection Methods group is responsible for the actual certification, maintenance of certification records, and follow-up for periodic recertification. Special certification specifications prescribe the specific requirements that each operator or inspector must meet to attain certification for the process. When supplier personnel certification is necessary, the Nondestructive Test Inspection Methods group may have qualified vendor quality control personnel act for them if this is the most feasible and economical approach. The status of the supplier certification program is available to purchasing and inspection personnel through a tabulated list which is regularly updated, that shows suppliers with certified personnel and the types of certification.

N. AUDIT OF QUALITY PROGRAM PERFORMANCE

Quality Assurance personnel continuously audit, on a random, unannounced basis, quality program procedures, inspections, tests, process controls, and certifications performed in each area. The employees performing the audit have a background of experience in or thorough knowledge of the procedures and inspection operations being audited. In no instance is an employee assigned to audit an operation or function for which he has line duties or responsibilities. The audits consist of a review of completed quality operations and documentation, comparison with established requirements, notification of required corrective action, and follow-up to assess results of corrective action.

Audit personnel are under the direction of Chief of Quality Review. Responsible supervision review each audit and are responsible to establish corrective actions, institute more complete instructions, and undertake training programs when required.

O. DATA REPORTING AND CORRECTIVE ACTION

1. Parts Inspection

In the development program, the engineering personnel that make disposition of nonconforming material determine the extent of feedback of information to the supplier for corrective action.

In the prototype and production programs, procedures exist to process copies of quality review orders to the supplier or department supervisor responsible for the nonconformance. In the case of P&WA produced parts, the procedures require that a production foreman sign the quality review order prior to disposition and that a general foreman also sign it after a reject disposition. The foreman must complete a corrective action report indicating the cause and action taken to prevent recurrence. Suppliers, upon receipt of quality review orders for nonconformances, must take the action required to prevent recurrence and must forward a written statement of reason for the nonconformance and corrective action taken. Quality Review personnel review the corrective action for completeness and adequacy.

Quality Review procedures exist for the prototype and production programs for the coding and transfer of all nonconformances to a data collection system. Reports are generated with both detail and summary information for analysis by quality and production departments. From these reports, quality levels for suppliers and categories of parts are obtained.

2. Assembly and Test Inspection

In the development program, engineering personnel have the responsibility for the collection and analysis of all quality problems. In the prototype and production programs, quality review personnel process nonconformances in the same manner as for parts inspection, including prompt referral to production personnel involved and review of resulting

corrective action statements. Assembly and test nonconformances that involve part problems receive intensive review of each detail nonconformances by production, inspection, engineering, and quality review personnel for cause and corrective action.

3. Field Service Problem Reports

Field service problem reports are investigated by assigned quality assurance personnel to establish reasons for the problem and corrective action to prevent recurrence.

P. PHASE II-C ACHIEVEMENT SUMMARY

The significant quality control achievements during the Phase II-C program that will carry over into the Phase III program are:

1. Completion of quality assurance data sheets that established quality requirements for engine parts
2. Preparation of inspection method sheets for inspection of rotating and critical parts
3. Updating of quality standards and methods specifications to the requirements of the JTF-17 engine
4. Development of blade and vane wall thickness measurement techniques and equipment
5. Procurement of special gages and tooling. Examples are pressure test fixtures and disk etch fixtures.
6. Modification of inspection facilities to accommodate the largest engine parts and permit reasonable speed of operation. Examples are to speed up rotation of the 84-inch Rotab and to provide 8-ft fluorescent penetrant tanks.

Several examples of documents prepared during Phase II-C that will carry over into Phase III are shown in Exhibit A. These documents are:

1. Quality Assurance Data Sheet for Part No. 2116523
2. Inspection Methods Sheet for Part No. 2116523
3. Methods Specification ECM-301
4. Quality Standard XRS-308.

Q. ADDITIONAL DOCUMENTS, SPECIFICATIONS, PROCEDURES, AND SPECIAL FORMS

Exhibit B includes the following documents, specifications, procedures, and special forms that amplify the Quality Assurance Program:

1. Engine History Record Sheet Number 914
2. Quality Assurance Procedure 2-E-11
3. PWA-QA-6064 - Supplier Quality Control Requirement
4. PWA-QA-6068 - Supplier Quality Control Requirement
5. PWA-F-3738 - Supplier Quality Control Survey for PWA-QA-6064
6. PWA-F-3739 - Supplier Quality Control Survey for PWA-QA-6068
7. PWA-10207 - Dimensional Record
8. PWA-F-1652 - Quality Review Authorization
9. PWA-F-39 - Quality Review Order
10. PWA-F-288 - Laboratory Quality Review Order

11. PWA-F-3628 - Corrective Action Report
12. PWA-F-1269 - Quality Review Investigation Report
13. Process Operation Procedure Number 294
14. Engineering Instruction Number 99
15. Gage Inspection Instruction
16. Calibration Instruction
17. Gage Inspection Record
18. PWA-300 - Laboratory Control of Material and Parts
19. PWA-310 - Identification Marking, Materials and Items
20. PWA-311 - Identification Marking, Spare Parts Packaging
21. PWA-354 - Age Control of Synthetic Rubber
22. PWA-381 - Shipping Closures
23. PWA-382 - Handling of items requiring special protection
24. PWA-F-3032 - Engineering Source Approval Part No. 2116523 data sheet.

EXHIBIT A TO SECTION III
EXAMPLES OF DOCUMENTS PREPARED
DURING PHASE II-C

The following pages present examples of documents prepared during Phase II-C that will carry over into Phase III. These documents are:

1. Quality Assurance Data Sheet for Part No. 2116523
2. Inspection Methods Sheet for Part No. 2116523
3. Methods Specification ECM-301
4. Quality Standard XRS-308.

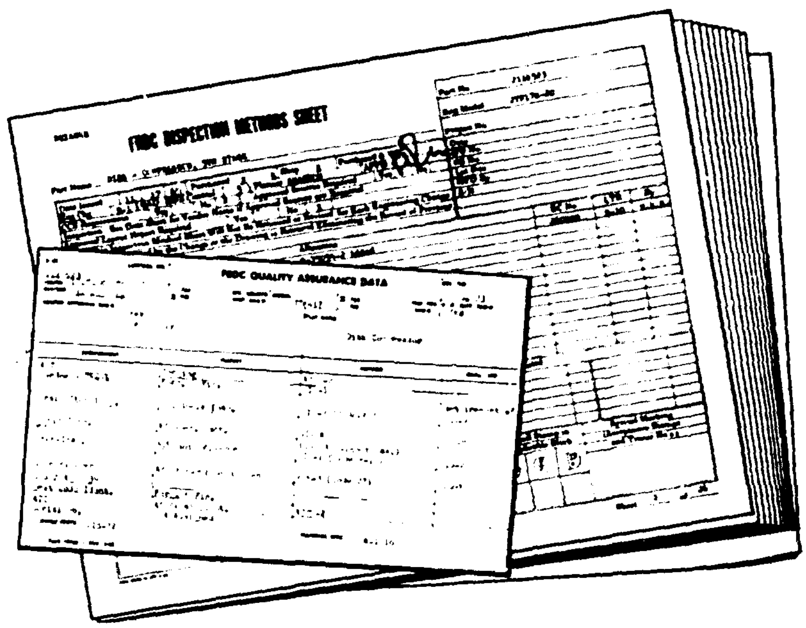


Figure 1. FRDC Quality Assurance and Inspection Methods Sheets

FD 17174
FIIIA

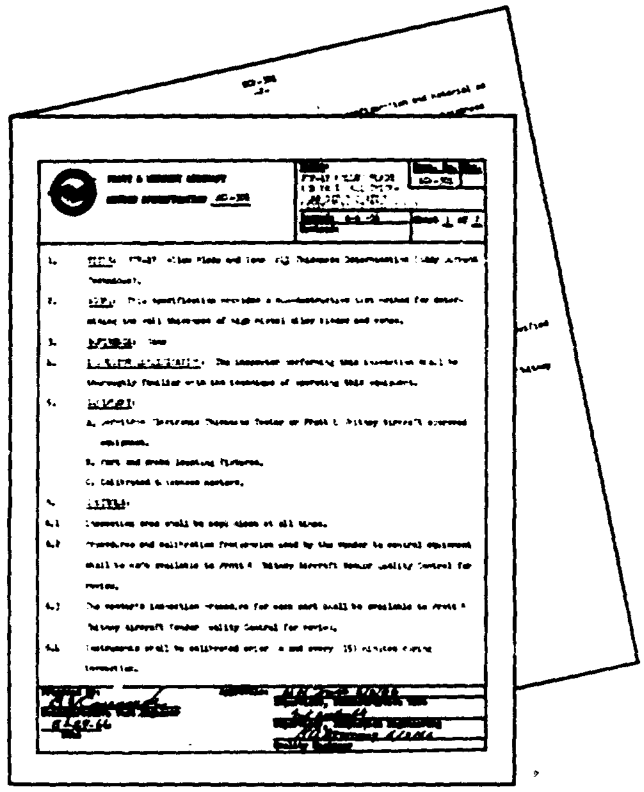


Figure 2. P&WA Method Specification ECM-301 FD 17175 FIIIA

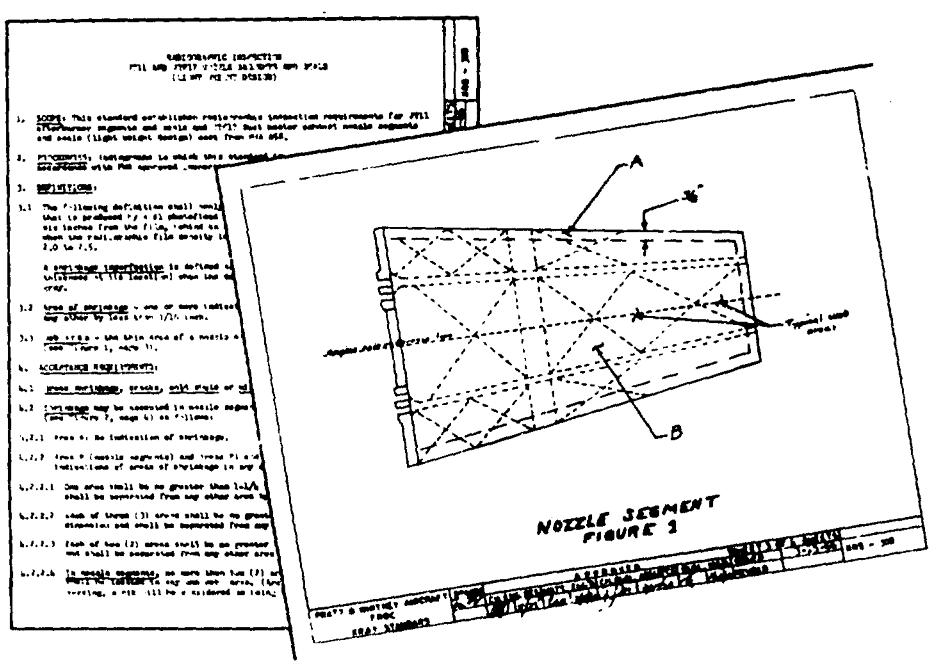


Figure 3. Radiographic Inspection Sheets FD 17176 FIIIA

EXHIBIT B TO SECTION III
ADDITIONAL DOCUMENTS, SPECIFICATIONS, PROCEDURES, AND SPECIAL FORMS

The following pages present documents, specifications, procedures, and special forms that amplify the Quality Assurance Program. These are:

1. Engine History Record Sheet Number 914
2. Quality Assurance Procedure 2-E-11
3. PWA-QA-6064 - Supplier Quality Control Requirement
4. PWA-QA-6068 - Supplier Quality Control Requirement
5. PWA-F-3738 - Supplier Quality Control Survey for PWA-QA-6064
6. PWA-F-3739 - Supplier Quality Control Survey for PWA-QA-6068
7. PWA-10207 - Dimensional Record
8. PWA-F-1652 - Quality Review Authorization
9. PWA-F-39 - Quality Review Order
10. PWA-F-288 - Laboratory Quality Review Order
11. PWA-F-3628 - Corrective Action Report
12. PWA-F-1269 - Quality Review Investigation Report
13. Process Operation Procedure Number 294
14. Engineering Instruction Number 99
15. Gage Inspection Instruction
16. Calibration Instruction
17. Gage Inspection Record
18. PWA-300 - Laboratory Control of Material and Parts
19. PWA-310 - Identification Marking, Materials and Items
20. PWA-311 - Identification Marking, Spare Parts Packaging
21. PWA-354 - Age Control of Synthetic Rubber
22. PWA-381 - Shipping Closures
23. PWA-382 - Handling of items requiring special protection
24. PWA-F-3032 - Engineering Source Approval Part No. 2116523 data sheet.

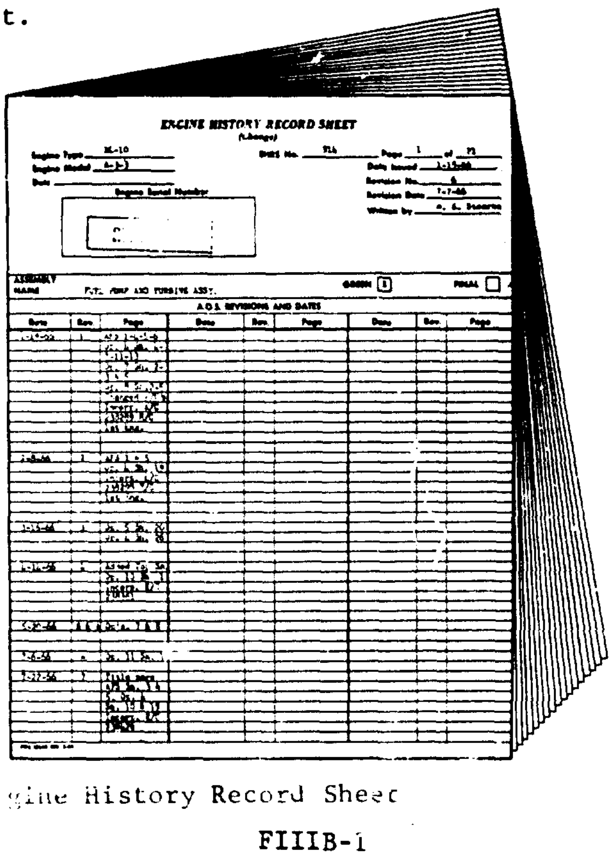


Figure 1. Engine History Record Sheet

FD 17177
FIIIB

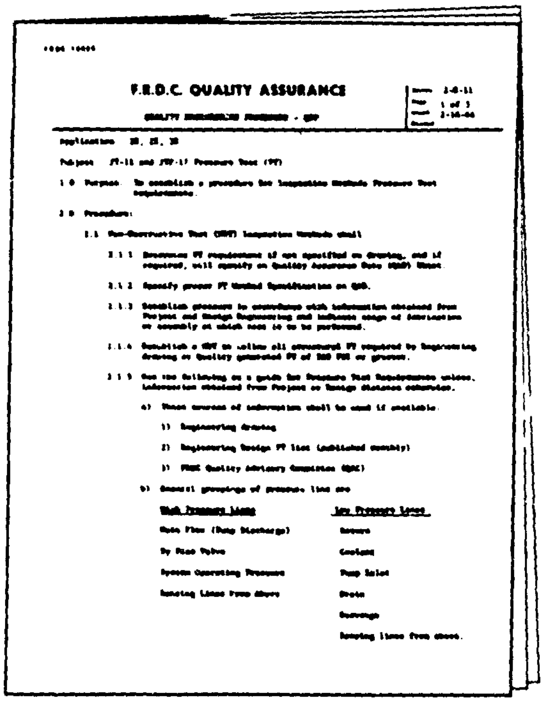


Figure 2. Quality Engineering Procedure - QEP

FD 17178
FIIIB

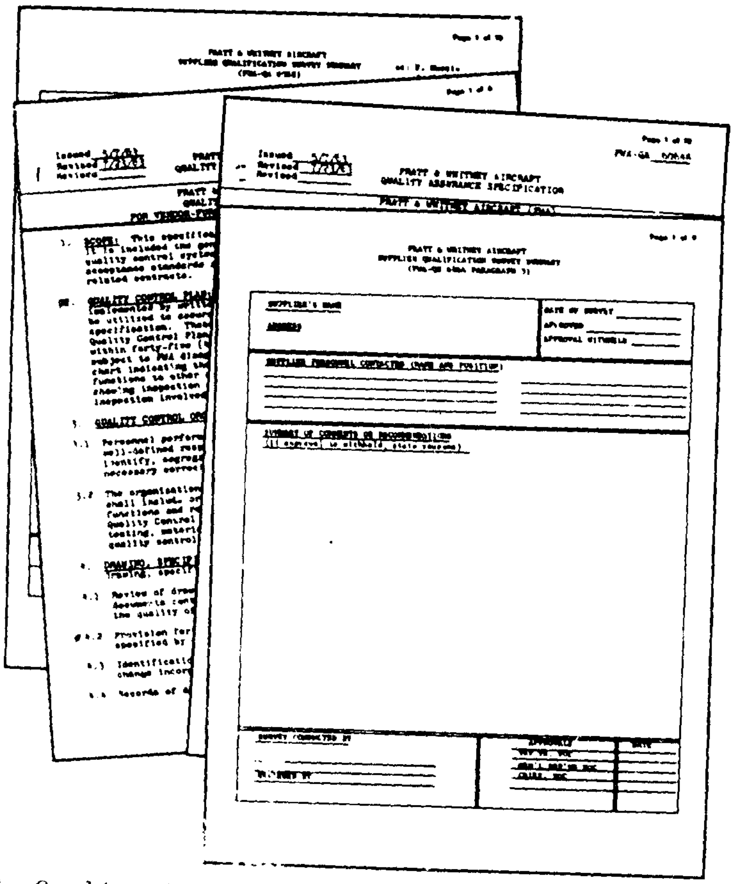


Figure 3. Quality Assurance Forms

FD 17179
FIIIB

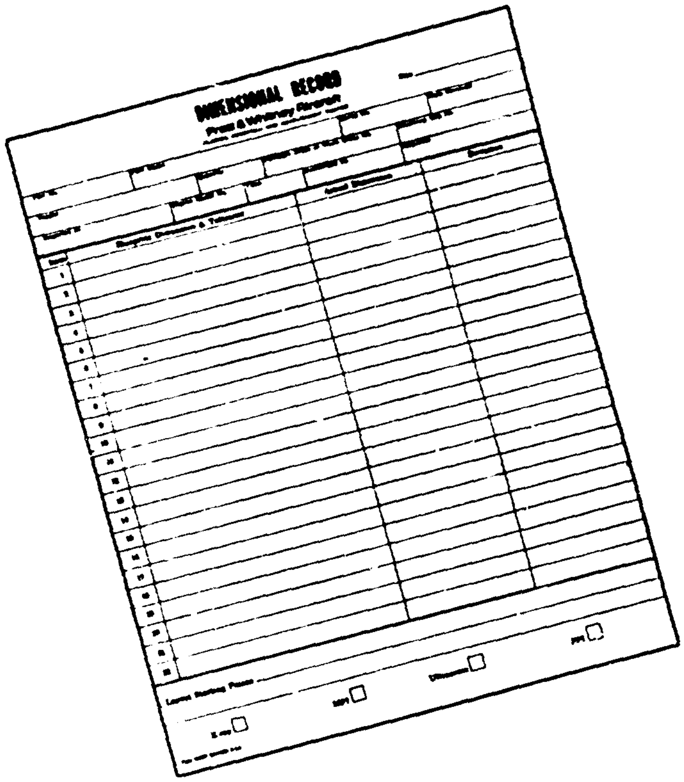


Figure 4. Dimensional Record

FD 17180
FIIIB

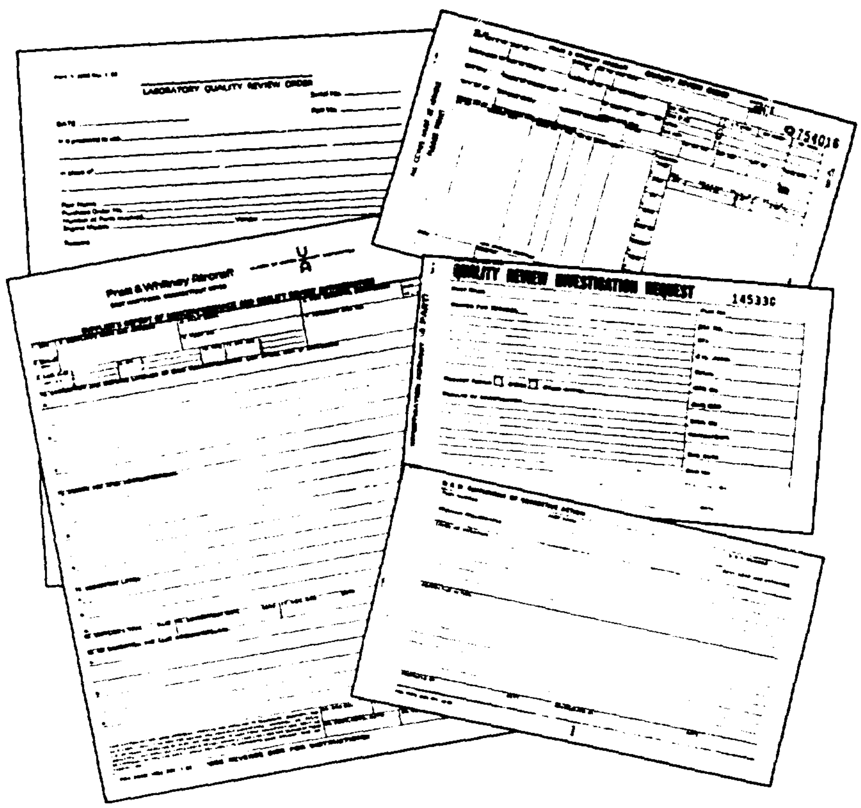


Figure 5. Quality Review Sheets

FD 17181
FIIIB

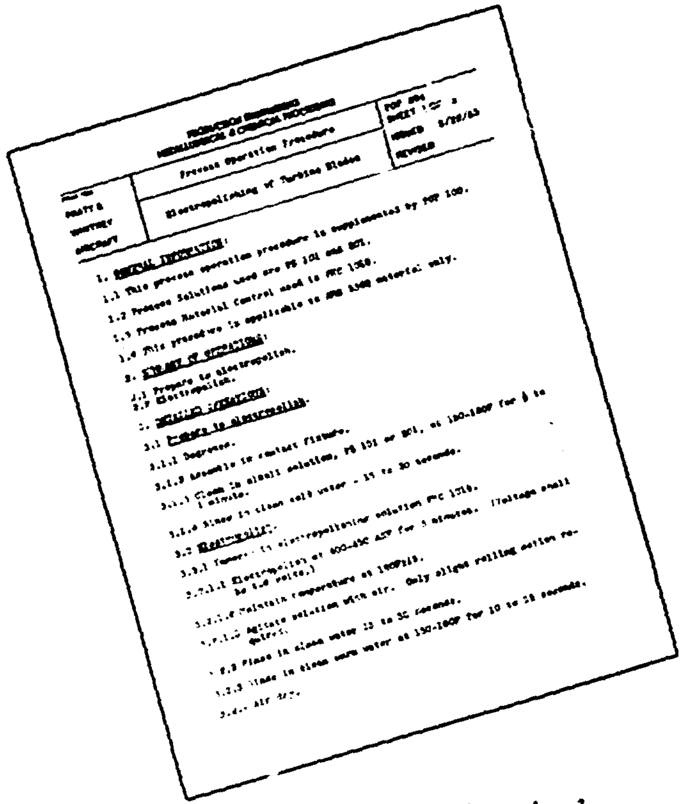


Figure 6. Production Engineering Metallurgical and Chemical Processing Sheet

FD 17182
FIIIB

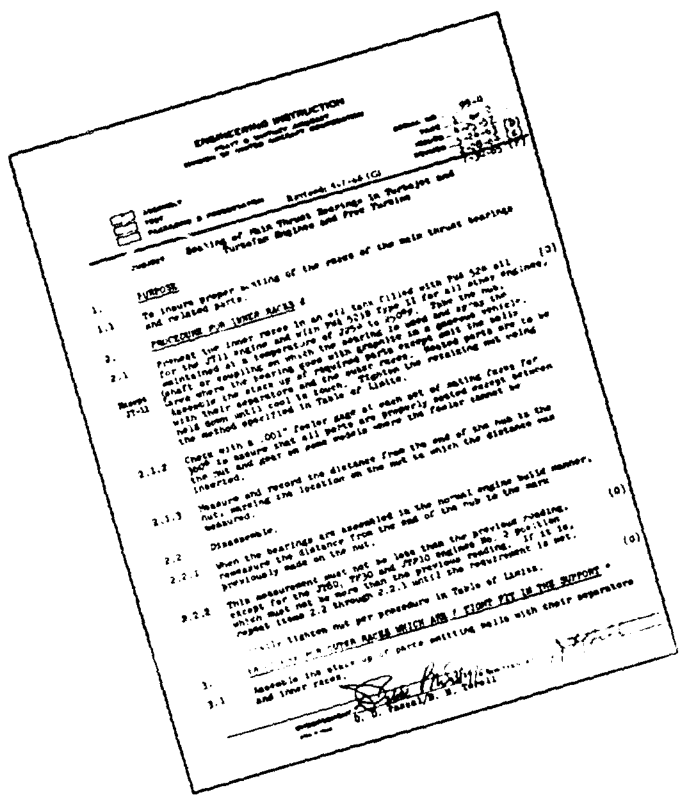


Figure 7. Engineering Instruction Sheets

FD 17183
FIIIB

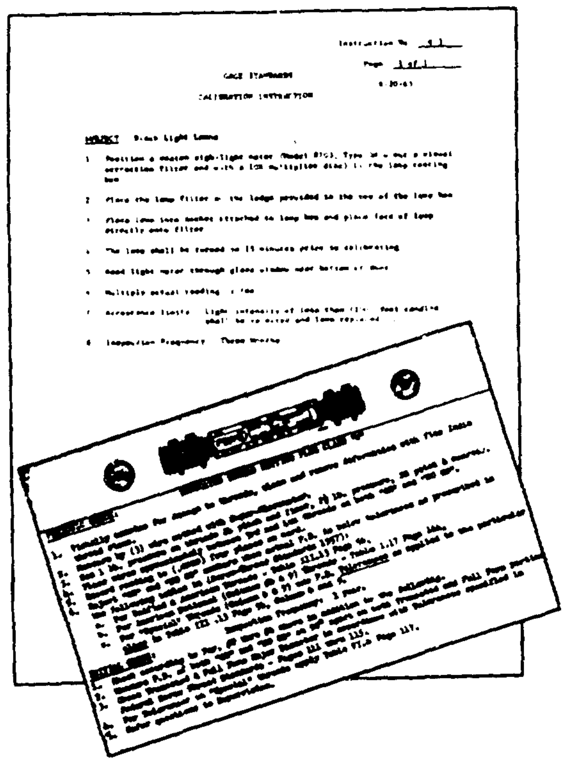


Figure 8. Gage Standard Forms

FD 17184
FIIIB

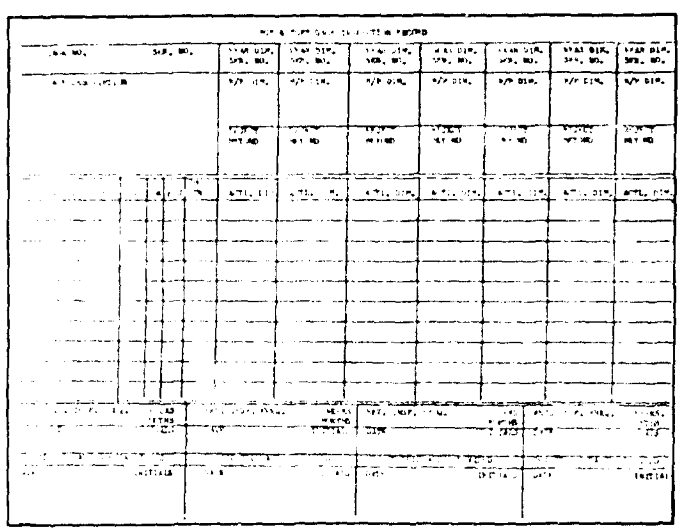


Figure 9. G and GF Gage Inspection Record

FD 17185
FIIIB

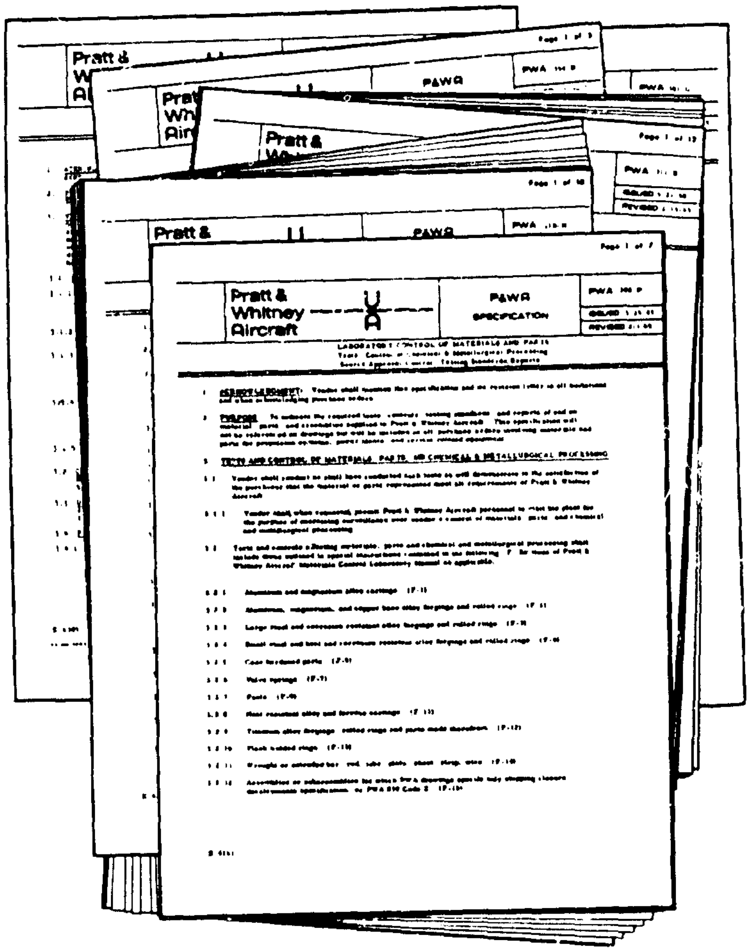


Figure 10. P&WA Specifications

FD 17186
FIIIB

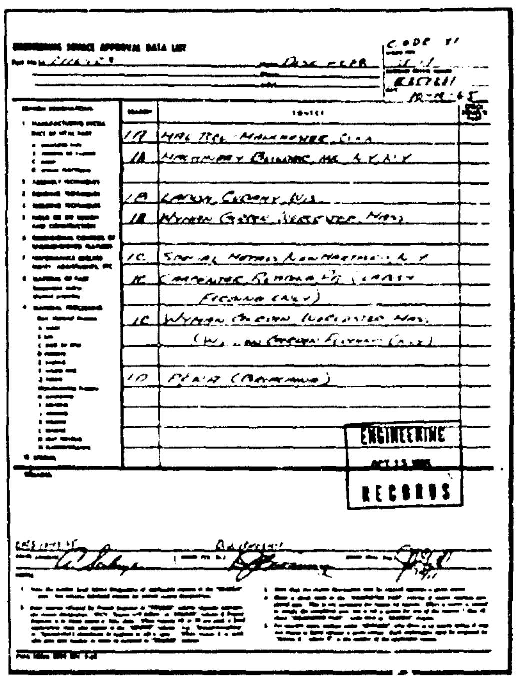


Figure 11. Engineering Source Approval Data Sheet

FD 17187
FIII3

SECTION IV
VALUE ENGINEERING PROGRAM

A. OBJECTIVES

The Phase III Value Engineering program objective is to achieve the required functions at the least overall cost throughout JTF17 engine design, development, manufacturing, and testing. To achieve this objective the functional approach is applied in every aspect of the JTF17 program.

Important secondary objectives are to assure the implementation of functional analysis, to foster cost awareness at each step of design and development, and to coordinate the most efficient interaction of all VE efforts.

B. SUMMARY

Consistent with the overall program objective of producing a supersonic commercial transport with satisfactory safety and economic characteristics, Pratt & Whitney Aircraft has established a VE program for the JTF17 engine.

Relating this program to SST engine requirements, the following are provided:

1. A VE Engineer who controls the integrated VE activities and functions
2. An organization composed of representatives of key disciplines who utilize function-oriented methods, procedures, equipment, and experienced personnel in a systematic effort to optimize or reduce cost
3. A review of subcontractor drawings and specifications and required contractor participation in the VE program
4. A training program to indoctrinate personnel in VE
5. A formal reporting system for initiation, follow-up, and documentation of cost savings attributed to the SST Program, and for assessing progress toward target costs. (Present target cost derivation is described in the Phase II Summary, Paragraph D of this Section.)

C. ORGANIZATION

The VE Engineer reports directly to the Manager, JTF17 Product Assurance, who in turn reports to the JTF17 Program Manager.

The Product Assurance organization will provide positive management control of the related disciplines of safety, reliability, maintainability, quality assurance, human engineering, value engineering, and standardization. It is an organization well suited to coordinating the airframe, engine,

airlines and Federal Aviation Agency requirements in these areas. The assignment of a single individual responsible for each discipline will improve communications between Pratt & Whitney Aircraft and the organizations named above. The Product Assurance organization is described and illustrated in Volume V, Report I.

The VE Engineer directs and controls all the tasks described in this VE plan. The organization for the implementation of this plan is shown in figure 1. The responsibilities of each element of this organization are defined in the following paragraphs.

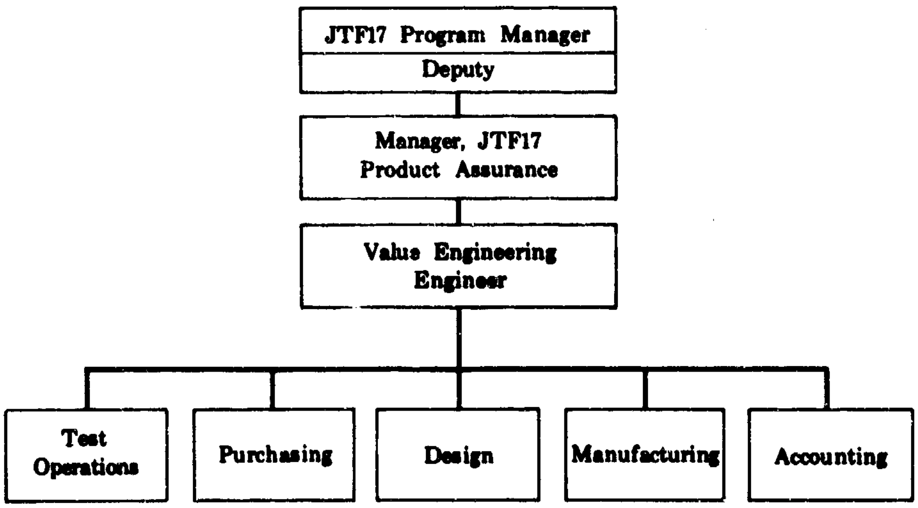


Figure 1. Value Engineering Organizational Chart FD 17510

1. Responsibilities

Responsibility for each facet of the VE effort rests with the interests affected by the particular cost decision.

a. VE Engineer

The VE Engineer directs individual departmental efforts and assures emphasis on overall cost. He will:

1. Define the overall program policy as it relates to VE
2. Establish and disseminate policy on the relationship between VE and other program considerations
3. Set realistic targets consistent with the goals and problems of the overall program (this relates to trade-offs that pertain to weight, reliability, maintainability, etc.)
4. Place emphasis on areas of high cost and maximum potential reduction with specific schedules for evaluation of progress on high-cost areas

5. Ensure the efficient interaction of efforts; for example, Design support for Production's fabrication ideas or Purchasing support for Design's alternative configurations

6. Continuously evaluate the status of the program

7. Report progress on the VE program to the Manager JTF17 Produce Assurance, relating cost status to predefined targets

8. Ensure adequate training and indoctrination of all personnel to provide:

   (a) A program-wide awareness of operating cost

   (b) Coordination of VE efforts with divisional and corporation-wide cost reduction programs

   (c) Determination of qualification or test requirements for all VE proposals

   (d) Direction of cost reduction efforts on proprietary items requiring vendor-furnished information

   (e) Relation of the effects of VE change proposals to development scheduling.

The VE Engineer will discharge the above operational responsibilities, with the assistance of VE personnel in various functional departments.

b. Value Engineering Activities

The responsibilities of the VE personnel in each department are described in the following paragraphs.

(1) Design Value Engineering Group

The Design VE Group is the principal operating arm of the VE Engineer. It is the responsibility of the Design VE Group to implement the VE plan, including both the cost reduction and report aspects. The group compiles engine costs and cost reduction progress, and assists the VE Engineer in setting realistic targets. Procedures for discharging these responsibilities are described in more detail in Paragraph D3a (Program Control).

(2) Representatives

The VE program requires a coordinated effort on the part of all personnel involved in the SST Program. For this reason, VE representatives are to be assigned full-time to the JTF17 program in each of the following operations.

(a) Purchasing

The representative from Purchasing acts as the focal point for all VE requests that require information from sources outside of the Division. The VE representative screens all inquiries for completeness of information, and date required. In most cases the inquiry consists of obtaining quotes for the Design VE Group on sketches depicting an alternative method of fabrication, or of material, or a combination of both. These inquiries are handled by the buyer responsible for that section of the engine. Information received is forwarded to the originator of the request after clearing through the Purchasing VE representative. When direct vendor contact is required to clarify a request or to study a sequence of operations, arrangements for such visits are conducted through the Purchasing VE representative.

(b) Manufacturing

Value Engineering responsibility in manufacturing is two-fold: to apply the functional VE approach to the manufacturing operation itself, with the objectives of minimum cost; and to support VE efforts as related to the engine design as consultant on manufacturing matters. The manufacturing VE representative is responsible for (1) determining the feasibility of substitute operations, (2) obtaining time estimates for alternative methods of fabrication, (3) advising on the purchase of new machinery, or (4) adapting existing equipment and tooling to meet specific needs. Specifically, he quickly evaluates the manufacturing feasibility of a VE inquiry. It should be noted at this point that VE efforts during Phase III will be aimed primarily toward Phase IV and Phase V manufacturing costs.

Conversely, his producibility evaluation of engine parts at the layout stage ensures identification and feedback of manufacturing problem areas. The restrictive feature is thus evaluated in its proper function of cost relationship.

(c) Test Operations

The Test Operations Representative is responsible for estimating the length of time necessary for various tests and the availability of the test facilities as this relates to the evaluation of a VE proposal. He also furnishes status on testing in progress and maintains a priority list, which is determined by the VE Engineer, of all future VE items requiring testing. The Test Operation VE Representative also makes recommendations on the use of alternative methods of testing. In addition to evaluating tests in progress, he originates and evaluates VE proposals that are directed at the maximum utilization of all of the test facilities. An important part of the test operations VE responsibility is the review of the designs of test equipment originating in the Facilities Design Group.

(d) Accounting

The representative from Accounting will furnish labor and overhead rates, and establish valid standards of cost comparisons for the evaluation of VE proposals. The Accounting Representative provides standard costs of production parts for all engines manufactured by P&WA. These

costs are an invaluable tool for cost comparison with parts having a similar configuration. He sees that these cost records are updated periodically and available to all VE personnel.

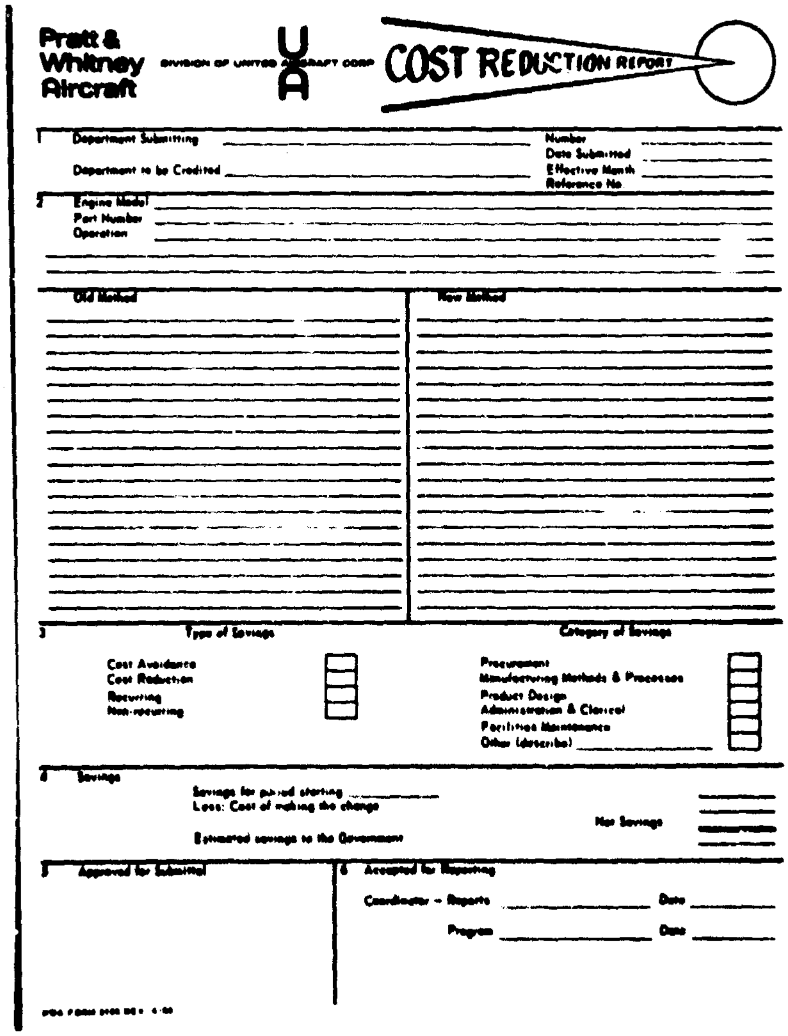
2. Personnel

Value Engineering functions are performed by personnel skilled in VE and also experienced and qualified in the functional requirements of their respective departments.

3. Relationship to Corporate Management

Value Engineering serves as one of the many parts of the corporate-wide cost reduction effort. Value Engineering's reporting procedures supply considerable input to overall cost reduction because of the similarity of ultimate objectives.

Divisional Cost Reduction Committees staffed by department managers have responsibility for implementing the cost reduction program and reporting to divisional and to corporate management. (The formal reporting system includes the form shown in figure 2.)


Pratt & Whitney Aircraft — Division of United Aircraft Corp

COST REDUCTION REPORT

1 Department Submitting ______ Number ______
Date Submitted ______
Department to be Credited ______ Effective Month ______
Reference No

2 Engine Model ______
Part Number ______
Operation ______

Old Method

New Method

3 Type of Savings

Cost Avoidance
Cost Reduction
Recurring
Non-recurring

Category of Savings

Procurement
Manufacturing Methods & Processes
Product Design
Administration & Clerical
Facilities Maintenance
Other (describe) ______

4 Savings

Savings for period starting ______
Less: Cost of making the change
Net Savings
Estimated savings to the Government

5 Approved for Submittal

6 Accepted for Reporting

Coordinator – Reports ______ Date ______
Program ______ Date ______

Figure 2. Cost Reduction Report

D. PROGRAM

The VE program will be integrated with the overall Phase III development program. Efforts are to be directed primarily at Phase IV and V manufacturing costs with due consideration also given to Phase III and IV development and experimental manufacturing costs.

1. Philosophy

It is recognized that no sacrifice in quality is permissible or necessary to attain the objectives of VE. High value is considered a basic consideration in good design and operating practice. Value Engineering is, then, not a special interest, but a tool of management for achieving the absolutely necessary goal of high value. It follows that the approach be quite basic.

1. The first step is to establish the function of an item of hardware or a procedure. For simplicity of description, consider only hardware, or components of the ultimate product, the JTF17 engine. Each part or component in the engine is to perform a function. The value engineering approach looks not at the part, but at the function. This approach retains the possibility of eliminating the part and performing the function elsewhere. A broad knowledge of engine design is required for such a determination. Limitations on performance of the function must be known, considering life, weight, environment, space, and compatibility.

2. Once a function is established, consideration can be given to alternative solutions. Though not limited to a checklist, the Value Engineer considers the following possibilities:

   a. Eliminate function
   b. Perform function elsewhere
   c. Combine function with another part
   d. Use less expensive material
   e. Use less expensive fabrication method
   f. Simplify manufacture, using present material and fabrication method
   g. Revise design approach.

Alternatives are always considered in the light of interaction with other parts and other program objectives.

1. After the more promising alternative solutions are established, further elimination must be based on carefully gathered and evaluated facts, not the least of which is cost. The necessity for all solutions to perform within the required functional limits is obvious. This determination is made during the initial round of elimination. Final elimination is on the basis of cost. A rough estimate of the alternatives, along with the current design, is made on the projected manufacturing

cost. In most cases, cost estimates are based on VE records and judgment, with consultation with VE representatives in operating departments. Vendor quotes and/or process planning summaries are used in cost trade studies and in engine cost estimates.

2. The VE cost reduction proposal is submitted after consideration of its effect on overall system cost, including the cost of implementing the change. This change implementation cost will be, of course, lower in Phase III than it will be in succeeding phases. Action on the proposal can be anything from rejection, through further evaluation, to immediate incorporation into the engine design. Each proposal is followed, by monthly reports to the Program Manager, to an ultimate decision, thus closing the VE-management loop.

2. Program Phases

As the SST Program progresses through prototype, production, and commercial service phases, the scope and implementation of the Value Engineering efforts are changed as necessary to meet requirements. The Value Engineering role in Phase III can best be described by reviewing the Phase II activity.

a. Cycle Selection

In the basic judgment of cycle selection, the VE approach was employed in its most basic form. Overall system cost advantages, inherent in the augmented, twin-spool, turbofan cycle, were detected by system function-cost analysis. These inherent cost advantages include:

1. Greater TSFC tolerance to off-design, i.e., subsonic missions, hot-day missions, etc.
2. Less costly duct heater manufacture and maintenance due to lower duct heater temperatures
3. Less costly hardware change required to exploit component improvements due to twin-spool versatility
4. Less costly hardware change required to meet post-certification growth requirements, i.e., changes made to low spool only
5. Greater TSFC tolerance to Mach number growth due to lower duct heater temperatures and twin-spool rematching versatility.

b. Initial Design

The initial manufacturing cost estimate for the JTF17 engine was made concurrently with initial design. This was accomplished by the Value Engineering Organization as described in the Phase II Summary Report. It is this organization that will provide the nucleus of the broader Phase III organization. This initial design cost estimate was only a part of the Value Engineering effort; considerable Value-Engineering-initiated cost reduction was included in the initial design itself. (Phase II reductions are reported in Paragraph E1c, with examples listed in table I.)

c. Prototype Design

Prototype design, by its very nature, is a solidification period with increasing cognizance of production considerations. It is considered the most crucial and the most productive phase for VE efforts. It is here that the engine designer must pay careful consideration to manufacturing, procurement, tooling, facilities, test, etc. Overall system cost can be minimized by relating the effect of the engine design to all these and other aspects of the program. It is this conception of VE's scope in Phase III that explains the broad organization described in Paragraph C of this Section.

3. Elements of the Program

a. Program Control

The VE Engineer controls the overall VE program through his assessment of cost status, setting of goals, placing of emphasis, and continuous followup. These control elements are described as follows.

(1) Present Status

This is represented by the cost baseline breakdown in its latest updated version.

(2) Goals

This is represented by the target cost breakdown. The target is the lowest realistically attainable manufacturing cost, broken down through consideration of high cost areas, anticipated problems, and areas of expected advances in technology. Scheduled reports include specific reference to progress relative to this target cost breakdown.

(3) Emphasis

High cost problem areas are identified and emphasized to the Program Management by the Value Engineer as a means of coordinating interdepartmental efforts.

(4) Followup

All pending proposals are retained in monthly reports until either implementation results or considered rejection has been made by Program Management.

(5) Program Reviews

The flow chart shown in figure 3 illustrates the closed loop progression of events used in the VE program control. The chart indicates the procedures used to provide a continuous review of design, with emphasis on high cost functions. Value Engineering then supports the designer with cost trade studies and in-process review and recommendations, in addition to the usual design-value aids. Design layout completion is then followed by design layout review in which VE participates to ensure high value design.

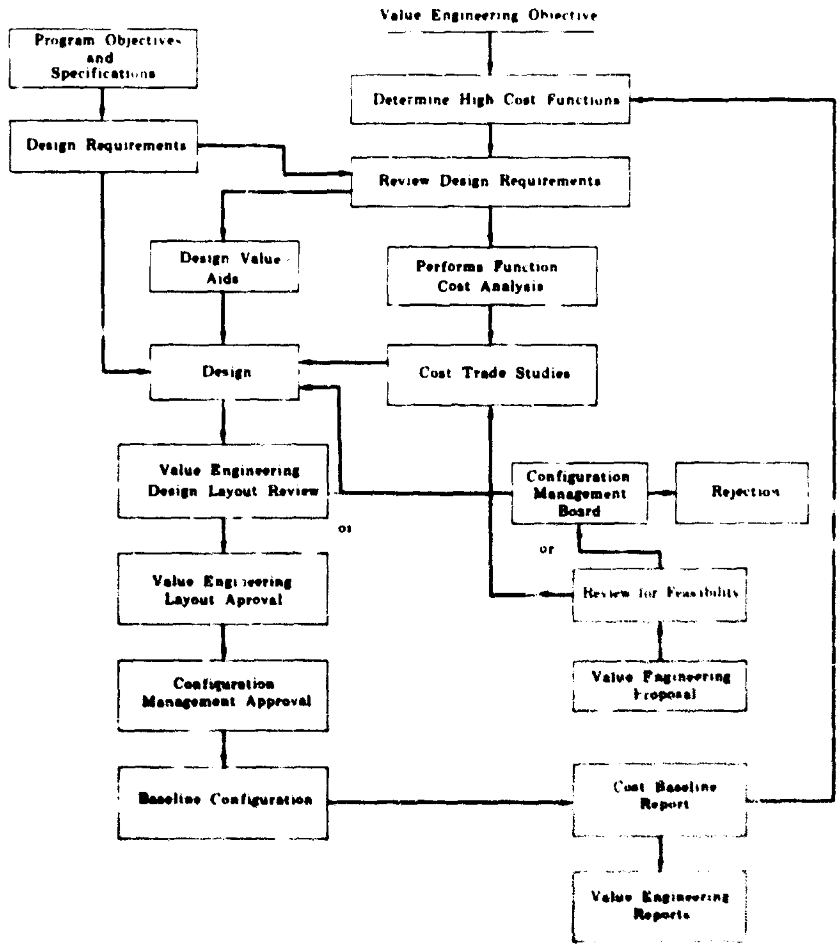


Figure 3. Value Engineering Flow Chart FD 17512

The VE layout review results in either approval by the Value Engineer or his delegate, or the issuance of a VE proposal. After review for feasibility, the proposal is either submitted to design or the Configuration Management Board for possible incorporation. In cases of disagreement, the Board will direct acceptance of the proposal, additional trade studies, or rejection. These procedures provide continuous monitoring of the JTF17 engine design.

To assure that the benefits from our past experience are reflected in the design and development of the JTF17 engine, P&WA will hold design reviews by the P&WA Design Review Board.

The P&WA Design Review Board, made up of experienced Program Managers and other senior Development Engineers from FRDC and East Hartford, will meet periodically to a schedule established on the basis of major design accomplishments. The schedule for these reviews in Phase III is discussed in Volume V, Report C (Configuration Management Plan).

The Board's principal function in Phase III, as it was in Phase II-C, will be to contribute suggested solutions to SST development problems, and to review the design to assure that problems that arise, or have been previously experienced on other programs, are not inadvertently designed into the JTF17.

Major Program Reviews will be established in Phase III to provide for Government, airlines, and airframe visibility and participation. These Major Program Reviews will be discussed in detail in Volume V, Report C (Configuration Management Plan).

b. Extent of Coverage

The above elements serve the ultimate scope of VE interest and cover the entire program. Consistent with this objective, the extent of coverage includes:

1. Engine design
2. Make-or-buy decisions
3. Manufacturing processes
4. Purchasing procedures
5. Specification requirements
6. Development program
7. Tooling
8. Facilities
9. Test operations.

(1) Engine Design

The most profitable area for VE in a program is during the design of the product. Value must be designed into the product, and as early in the program as possible. Design VE procedures are oriented toward this timeliness. Providing tools, information, and motivation to help the designer achieve high value in initial design is a function of VE. The cost control function is thus performed in the following order:

1. Design-value aids
2. Cost trade studies
3. Design layout review
4. VE proposals

Value Engineering proposals appear last because every effort is first made to avoid the need for them.

(a) Design-Value Aids

Each designer is provided with Design-value aids to guide his initial design decisions. These aids provide the designer with ready suggestions and comparisons to facilitate informed, cost-oriented design decisions. Data used are constantly updated, especially with regard to addition of the more recently available high temperature materials and techniques. Some of the available charts and curves are listed below:

1. Relative costs per pound of forged materials (figure 1, Exhibit A)
2. Relative costs per cubic inch of forged materials (figure 2, Exhibit A)
3. Relative costs per pound of sheet materials (figure 3, Exhibit A)
4. Relative costs per cubic inch of sheet materials (figure 4, Exhibit A)
5. Compressor blade cost vs material (figure 5, Exhibit A)
6. Compressor vane cost vs material (figure 6, Exhibit A)
7. Compressor blade cost vs root configuration (figure 7, Exhibit A)
8. Turbine blade cost vs material (figure 8, Exhibit A)
9. Turbine vane cost vs material (figure 9, Exhibit A)

10. Relative machinability of various materials (turning, figure 10, Exhibit A; and drilling and reaming, figure 11, Exhibit A)
11. Relative weldability of various materials (fusion, resistance, electron beam) (table 1, Exhibit A)
12. Machining tolerance vs labor time
13. Relative costs of various coatings and platings
14. Cost of prefabricated materials such as honeycomb, Rigimesh, etc.
15. Relative costs of forgings vs size, complexity and type
16. Sheet metal thickness vs relative cost (figure 12, Exhibit A).

(b) Cost Trade Studies

Design decisions are given a cost dimension, where complex alternatives are considered, by the use of cost trade studies. The manufacturing cost of each design possibility is estimated; in most cases, similar parts on other engines are used as a basis for cost estimates. Adjustments are made through the use of operation-by-operation labor time records of the part or assembly. The detail drawing of this reference is thus matched against the proposed design. Vendor quotes and/or process planning summaries are obtained for increased accuracy. Cost trade studies can be initiated by the cognizant designer, and also by Project Engineering or by the Value Engineer.

(c) Design Layout Review

Each design layout is reviewed by VE periodically during design and immediately prior to release. Though designers consider fabrication cost as a matter of course, reminders from the Value Engineer ensure an awareness of the latest developments and techniques. The Value Engineer's effectiveness is enhanced by knowledge of cost trade studies in other areas, recent developments in fabrication techniques, and incoming suggestions from production and vendor sources. The final review prior to release gives the Value Engineer an opportunity to follow up earlier suggestions and to initiate VE proposals where cost reduction potential remains. (Figure 13, Exhibit A, shows the form used for layout review.) The follow-up space on the form is used to assure closed-loop action on all recommendations. The details of the closed loop control system, of which the Design Layout Review is an integral part, has been discussed earlier in paragraph D3a(5).

(d) Value Engineering Proposals

Value Engineering proposals provide the method by which the Value Engineer can present a cost reduction idea in the concise form necessary in a development program. The form (figure 14, Exhibit A) presents the idea, shows before and after sketches, and indicates feasibility through approval signatures of cognizant personnel representing specialized design interests. These approvals--representing stress, heat transfer, vibrations, fluid flow, performance, weight, reliability, and maintainability--imply feasibility, not absolute approval. Follow-up by VE on its proposals is aimed at implementing the cost saving by solidifying the cost estimate and the analytical backup. Follow-up also will include a periodic cost reduction report which will appraise progress and remind management of still pending proposals.

(2) Make-Or-Buy Decision

Though the make-or-buy decision is not within the province of Value Engineering, VE will anticipate the decision for estimating purposes, and to make recommendations wherever applicable. The original engine cost estimate was based on the VE assumed make-or-buy plan which was based on historical reference. Wherever a reversal of make-or buy decision will result in a cost reduction, such a recommendation will be made by VE.

(3) Manufacturing Processes

Though Value Engineering's primary interest in manufacturing relates to its influence on engine design, the extent of coverage also includes the manufacturing operation itself. The Value Engineering functional approach is to be applied to equipment procurement, machine loading, and fabrication process development.

(4) Purchasing Procedures

Value Engineering interest in purchasing procedures relates primarily to the effectiveness of securing minimum prices on all purchased parts and raw material. Effective vendor correspondence, including feedback of fabrication problems and cost saving alternatives, are among the value controls at the disposal of Purchasing. Appropriate VE clauses are included in large purchase orders.

(5) Specification Requirements

These are reviewed by VE to determine the requirement-cost relationship. Functional value vs cost is as significant here as in hardware design. This relates to performance specification requirements imposed on the engine as well as material specifications imposed on vendors.

(6) Development Program

It is necessary to consider the entire development program in any attempt to effectively promote a Value Engineering effort. Suggestions that will significantly change the leadtimes on pacing items can result in a revised development program. A continuing review of the program is required; it may be necessary to revise procurement schedules to take advantage of improved design alteratives. Results of preliminary testing might indicate revisions that must be initiated as soon as possible. Change is normal in a development program, and the Value Engineer must be ready to take full advantage of changing requirements as they develop. Close liaison with both Project Engineering and the Design Value Engineering Group will be provided by the VE Engineer.

(7) Tooling

The choice of tooling can have a significant effect on cost. It is necessary that the quantities of parts to be fabricated be clearly understood, and that close liaison exist between the project, design, manufacturing, and tool design Value Engineering representative. The areas of the design that are firm should be immediately made known to tool design so that they can take advantage of tooling for quantity production. Areas of the design that are firm, but that have specific areas subject to change, can be identified, and suitable allowances made in the event of a change. Temporary tooling can be used on any part of the design that is expected to change.

(8) Facilities

Existing facilities lists must be examined in the light of present and future requirements. The quantity and type of facility corresponds to overall project needs. However, Value Engineering effort will be most effective in the decision to obtain new facilities and in the way in which existing facilities can be modified to produce a given result. This requires a continuing appraisal by Value Engineering representatives from Project Engineering and Test.

(9) Test Operations

Within the limits of defined test schedules and facilities availability, engine and component testing involves a considerable latitude for cost affecting decisions. Application of the VE functional approach ranges from fuel utilization to personnel scheduling. The Integrated Test plan is responsive to these considerations. (Refer to Report E, Section I.)

c. Training and Indoctrination

Training lectures and motion pictures illustrating the techniques and purposes of VE have been presented to design personnel over the past 5 years. A 150-page VE handbook has been prepared and distributed to key personnel by the Design VE Group. Symposiums and training seminars have been attended by key engineering, design, manufacturing, training, and purchasing personnel. This training is continuous to keep abreast of new methodology in the VE field as well as in the utilization of high-temperature metal technology and other advances. These training procedures complement the design value aids, paragraph (a) above, as a means of designer motivation. Phase III will see an increased emphasis on the workshop-seminar training technique. Actual practice is considered the best way to teach the VE approach.

d. Subcontractor Value Engineering Direction

Pratt & Whitney Aircraft Value Engineering helps initiate and direct Value Engineering programs at vendors' and subcontractors' facilities. Frequent meetings with vendors and visits to their facilities serve to stimulate mutual interest in reducing costs. This, in turn, creates a willingness to participate in a Value Engineering effort. The initiative and interest shown by vendors and subcontractors is noted by Purchasing as a measure of job performance. This serves as additional motivation on the part of the vendors to contribute to an effective Value Engineering program. The Value Engineering coordinating group has supplied speakers to talk to organizations composed chiefly of vendors' and subcontractors' representatives to explain Pratt & Whitney Aircraft's interest in applying Value Engineering to all engine components.

Through the purchasing function of Value Engineering, vendors are urged to make design recommendations in the interest of cost reduction. Thorough discussion of actual performance requirements of the purchased item are used to facilitate this approach. The vendor thus becomes an integral part of the total Value Engineering plan.

e. Reports and Documentation

Both the appraisal and the effective utilization of the overall Value Engineering program require a comprehensive system of reporting and documentation. The scope of reporting will include the following:

1. Keep management apprised of projected manufacturing cost reflected by current design
2. Report cost reduction status; i.e., total cost reduction incorporated and total pending
3. Report status of progress relative to target cost breakdown
4. Define problem areas and provide scheduled evaluation
5. Report status of current make-or-buy intent.

These reporting requirements are to be included in the following report schedule.

1.	Engine Cost Report	Monthly
2.	Cost Reduction Summary	Bi-Monthly
3.	VE Proposal Status	Bi-Weekly

E. PHASE II SUMMARY REPORT

1. Phase II Accomplishments

Phase II has seen Pratt & Whitney Aircraft's existing Value Engineering organization adapted to the JTF17 program. This adaptation included the gathering and making available of pertinent background information and the establishment of specific operating procedures.

a. Background Information

The broad scope of the JTF17 VE program has necessitated the intensified accumulation of information pertinent to manufacturing cost of commercial engines in production quantities.

The Standard Cost Runoff, listing the cost of every current production part, is available and maintained up-to-date. Also available is the Labor and Standard Operation Cost file, which itemizes the labor cost of each operation in the manufacture of each production part made. Prints of each of the corresponding parts and assemblies are also available.

To facilitate the original JTF17 engine cost estimation, vendor quotes and labor estimates were obtained on J58 engine parts and components in SST quantities.

Subsequent up-dating of manufacturing cost estimates using vendor quotes and process planning summaries from actual JTF17 engine detail drawings has resulted in the accumulation of background information on the capabilities of production vendors and of our own production facilities.

b. Procedures Established

Operating procedures for the Value Engineering operation during Phase II have been established with an eye toward expansion into Phase III. Most of the Phase II Value Engineering effort has taken place in, and emanated from the Design Department. It is these Design Value Engineering procedures that will carry over, with increased scope, into Phase III; they are described briefly on the following page.

1. Design Layout Review - each layout reviewed by a Value Engineer for suggestions and/or further study toward the end of minimizing overall cost.
2. Value Engineering Proposals have been issued for the purpose of advancing cost reduction suggestions in concise form accompanied by backup information and cost involved.
3. Cost trade studies have been made to support design decisions involving possible alternatives.
4. Target manufacturing costs have been established in sectional breakdown form for purpose of designer motivation and program evaluation.
5. Production Engineering suggestions resulting from process planning studies of test engine designs have been relayed to cognizant Design and Project engineers.
6. A baseline manufacturing cost has been calculated and is being maintained up-to-date by use of vendor quotes, production engineering planning summaries, and Design VE estimates.
7. Reporting procedures currently include:
   a. Value Engineering section of monthly report to FAA, Phase II-C
   b. Periodic summary of Value Engineering Proposals and other cost reduction efforts
   c. Baseline manufacturing cost up-date reports.

c. Cost Reductions

Phase II has seen extensive cost reduction reflected in the engine design as a result of Value Engineering efforts. Table 1 lists 14 accountable changes, totaling $24,882 per engine, that came directly from Value Engineering Proposals. Other proposals are still pending analytical substantiation and/or test verification. Table 2 lists 8 of the more promising cost reduction proposals totaling $14,401 per engine. Numerous other cost reduction change possibilities were washed away by unrelated component redesigns early in the design effort.

Table 1. Cost Reductions Completed

Engine Section		Description	Cost Reduction Per Engine	Figure Number (Exhibit A)
Fan				
	1.03	1st-Stage Inner Shroud - Sheet Metal in Place of Forging	$ 94	15
	1.07	Replace Honeycomb on Air Seal Between 1st- and 2nd-Stage with Machined Serrated Seal Lands	227	16

Table 1. Cost Reductions Completed (Continued)

Engine Section	Description	Cost Reduction Per Engine	Figure Number (Exhibit A)
1.09	Replace 1st-Stage Disk and Front Hub With Integral Disk and Hub	1611	17
Intermediate Case			
2.01	Replace Forged Struts with Sheet Metal Struts	2410	18
High Compressor Section			
3.05	Replace Honeycomb with Machined Serrated Seal Lands in 3rd- through 8th-Stages	875	19
3.07	Remove High Compressor Front Air Seal	5555	20
3.09	Change Cooling Air Bore Tube from Two Machined Forgings to a Weldment	715	21
3.10	Change Front High Compressor Hub Material from Waspaloy to Inco 901	670	22
Turbine Section			
5.01	Remove Lock Wire Tabs on 1st-Turbine Inner Shroud	130	23
5.16	Change Material of Turbine Rotor Outer Shrouds from Waspaloy to Hastelloy X	1069	24
5.17	Change Material of Low Turbine Shaft from Waspaloy to Inco 901	4884	25
Duct Heater Section			
6.04	Reduce the Size of the Nozzle End Support Forging and Extend the Sheet Metal Section	102	26
6.05	Shorten Duct Heater Approximately Six Inches	6040	27
Exhaust Section			
7.07	Cast Thrust Reverser Deflector Bearing Housing Instead of Forging	$ 500	28
		$24,882	

Table 2. Cost Reductions Pending

Engine Section	Description	Cost Reduction Per Engine	Figure Number (Exhibit A)
Fan			
1.04A	Change Material of Fan Coupling Nut from Inco 718 to AMS 6415	$ 50	29
1.08	Change Forged 2nd Stators and Duct EGV to Strip Stock	4260	30
High Compressor Section			
3.04A	Provide Strip Stock Stators in Place of Forged Vanes for 5th, 6th, and 7th Stages	5450	31
3.12	Change Material of Bleed Valve Housing From Cast Stellite 31 to Cast 347	180	32
3.14	Change Forged Inco 718 EGV to Inco 625 Strip Stock	1500	33
Turbine Section			
5.05	Change Compressor Shaft From Waspaloy to Inco 901	2365	34
5.06	Change High Turbine Inner Seal From Wa aloy to Inco 901	146	35
5.20	Change 2nd-Stage Front Cover Plate From Waspaloy to Inco 901	450	36
		$14,401	

d. Motivation

Motivation of personnel toward cost awareness has been approached from two paths; indoctrination in Value Engineering techniques, and by direct application of Value Engineering through design layout review, as follows:

1. Training sessions have been initiated with design personnel. "Live" Value Engineering Proposals are used with special emphasis on the functional analysis approach that had originated the proposal. The reasoning processes that lead to the ideas make up the principal message. Incentive is then provided by acquainting the designer with the dollar impact on the overall program.

2. Value Engineering layout review provides continuous and timely motivation by keeping cost consideration continuously before the Designer. The Designer is reminded to consider fabrication cost in each step of design, from the initial identification of function to the last surface finish designation. The Value Engineer's approval signature, required on all design layouts, then provides the final reminder and furnishes the Value Engineer with the opportunity to follow up earlier recommendations and to initiate Value Engineering Proposals where necessary.

2. Present Manufacturing Cost and Target Cost

The initial Cost Baseline Report was issued in December 1965 and updated in April 1966. Value Engineering supplied the basis for the Phase V manufacturing cost estimate included in this report. Purchased part, component, and raw material costs were based on vendor quotes, where time permitted, and on Value Engineering estimates in other cases.

Estimated labor times on parts to be fabricated at P&WA were based on process planning summaries by Production Engineering. Value Engineering estimates replaced process planning summaries where necessary.

This baseline Phase V manufacturing cost estimate, along with economic considerations and reference to high cost problem areas, has provided the basis for the target manufacturing cost. The engine sectional breakdown of this target cost provides an identifiable goal for Value Engineering efforts during Phase III. The identification of high cost problem areas and the target reductions assigned to the various engine sections were based on a detailed review of current estimates and on comparison to earlier estimates on the JTF17 and other engines. The sectional breakdown allows maximum target reductions to be assigned to specific engine sections and to specific design groups. The group effort toward a single, clearly drawn goal offers an extra measure of incentive.

Engine sections whose costs appear disproportionately high relative to other engines have been treated as problem areas and have received extra Value Engineering attention. Problem areas have also been detected where vendor quotes or Production Engineering estimates markedly exceed their corresponding preliminary Value Engineering estimates. This situation often precipitated Value Engineering Proposals.

EXHIBIT A TO SECTION IV
VALUE ENGINEERING AIDS

Some of the charts and curves available to the designer, providing him with ready suggestions and comparisons to facilitate informed, cost-oriented design decisions (see Section IV, paragraph D4b(1)(a)), are included in this Exhibit, and are listed below:

1. Relative costs per pound of forged materials (figure 1)
2. Relative costs per cubic inch of forged materials (figure 2)
3. Relative costs per pound of sheet materials (figure 3)
4. Relative costs per cubic inch of sheet materials (figure 4)
5. Compressor blade cost vs material (figure 5)
6. Compressor vane cost vs material (figure 6)
7. Compressor blade cost vs root configuration (figure 7)
8. Turbine blade cost vs material (figure 8)
9. Turbine vane cost vs material (figure 9)
10. Relative machinability of various materials (turning, figure 10; and drilling and reaming, figure 11)
11. Relative weldability of various materials (fusion, resistance, electron beam) (table 1)
12. Sheet metal thickness vs relative cost (figure 12).

Figure 13 shows the VE layout review form used to assist the Value Engineer to follow up earlier suggestions and to initiate VE proposals where cost reduction potential remains (see Section IV, paragraph D4b(1)(b). The follow-up space on the form is used to assure closed-loop action on all recommendations.

Figure 14 is the Value Engineering Proposal form, which provides the method by which the Value Engineer can present a cost reduction idea (see Section IV, paragraph D4b(1)(c). The objective of the form is to present the idea, show before-and-after sketches, and indicate feasibility through approval signatures of cognizant personnel representing specialized design interests.

Figures 15 through 28 show 14 accountable changes (referred to in Section IV, paragraph Elc), totaling $24,882 per engine, that came directly from Value Engineering proposals. Other proposals are still pending analytical substantiation and/or test verification. Figures 29 through 36 show 8 of the more promising cost reduction proposals (also referred to in Section IV, paragraph Elc) totaling $14,401 per engine.

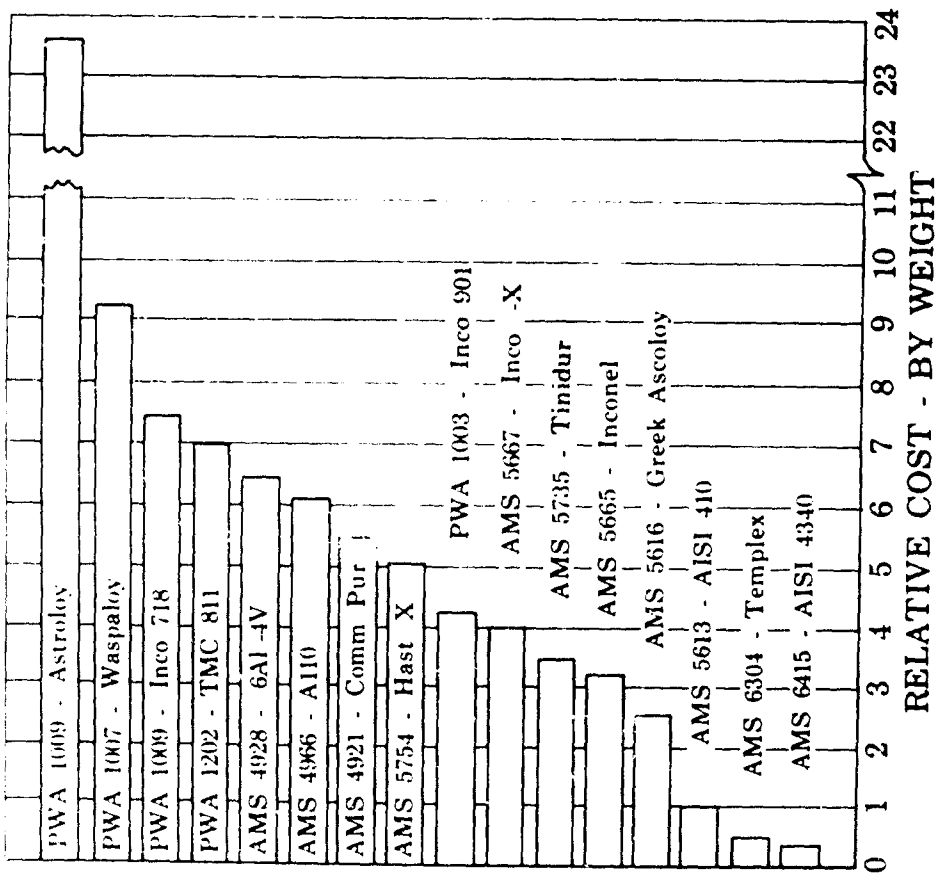


Figure 1. Relative Cost Per Pound of Forged Materials

FD 16317

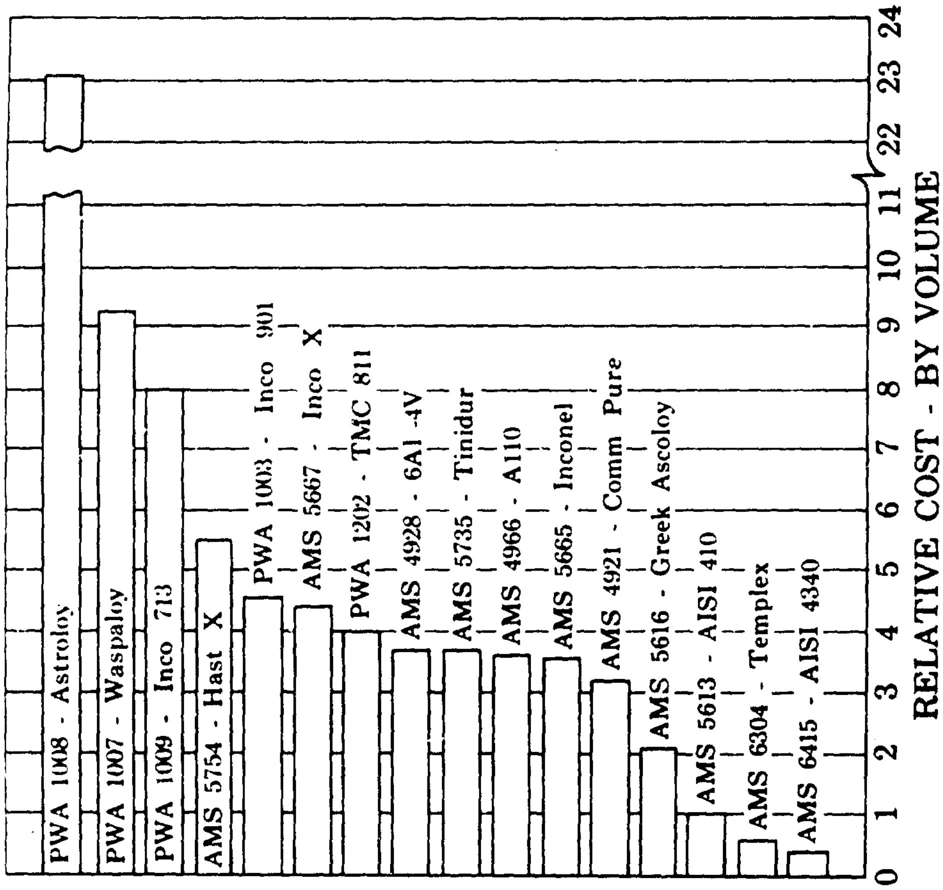


Figure 2. Relative Cost Per Cubic Inch of Forged Material

FD 16318

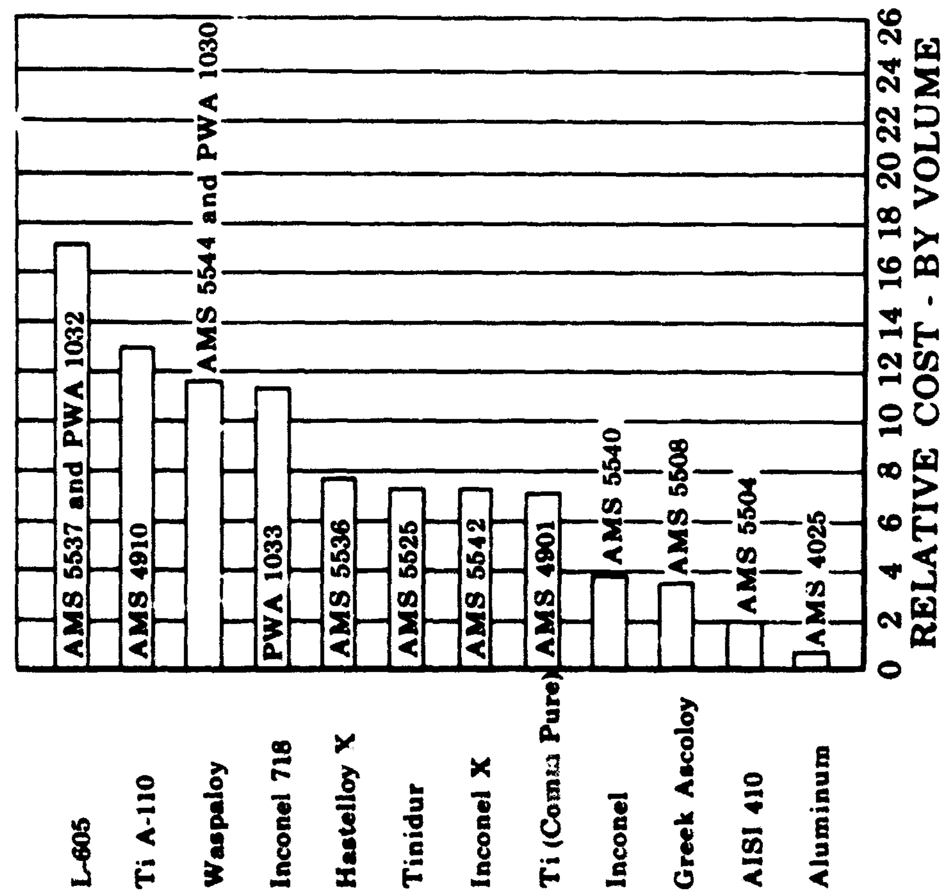


Figure 4. Relative Cost Per Cubic Inch of Sheet Materials FD 16320

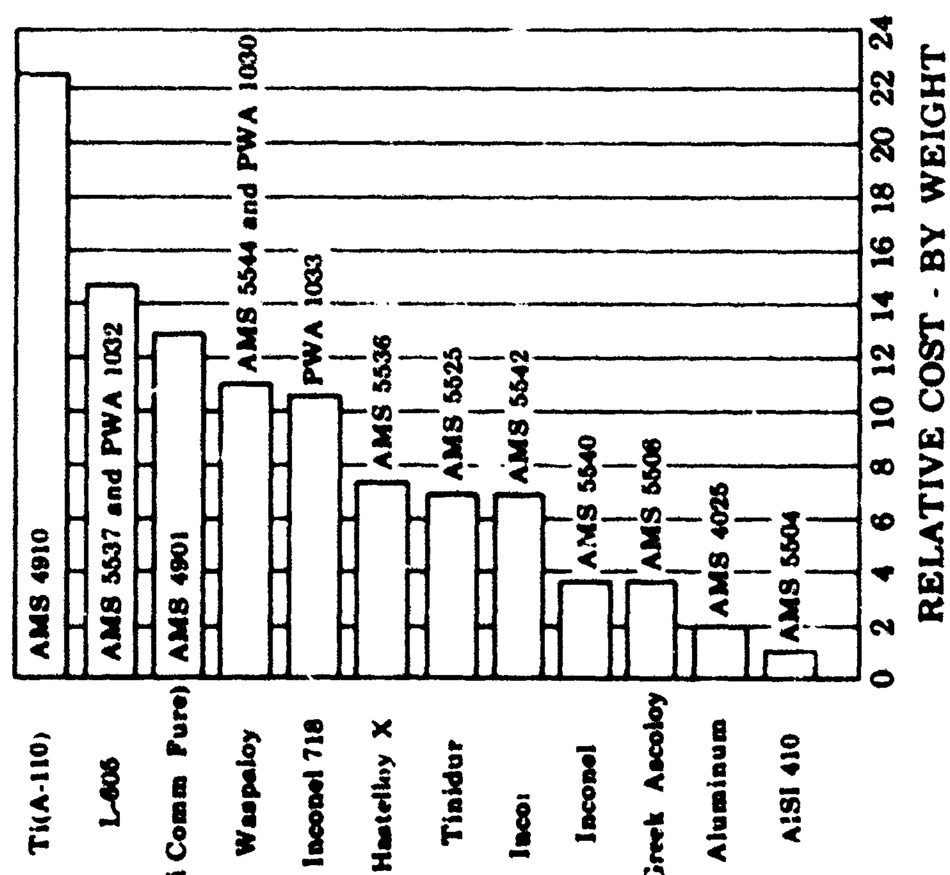


Figure 3. Relative Cost Per Pound of Sheet Materials FD 16319

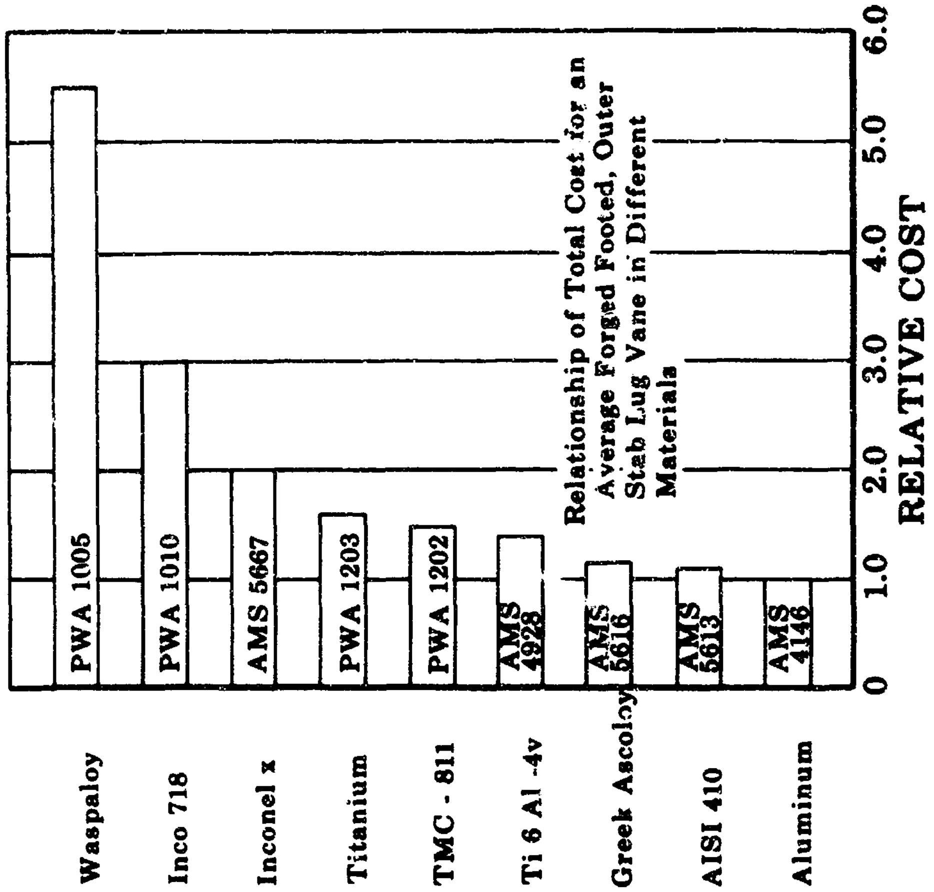


Figure 6. Compressor Vane Cost vs Material FD 16323

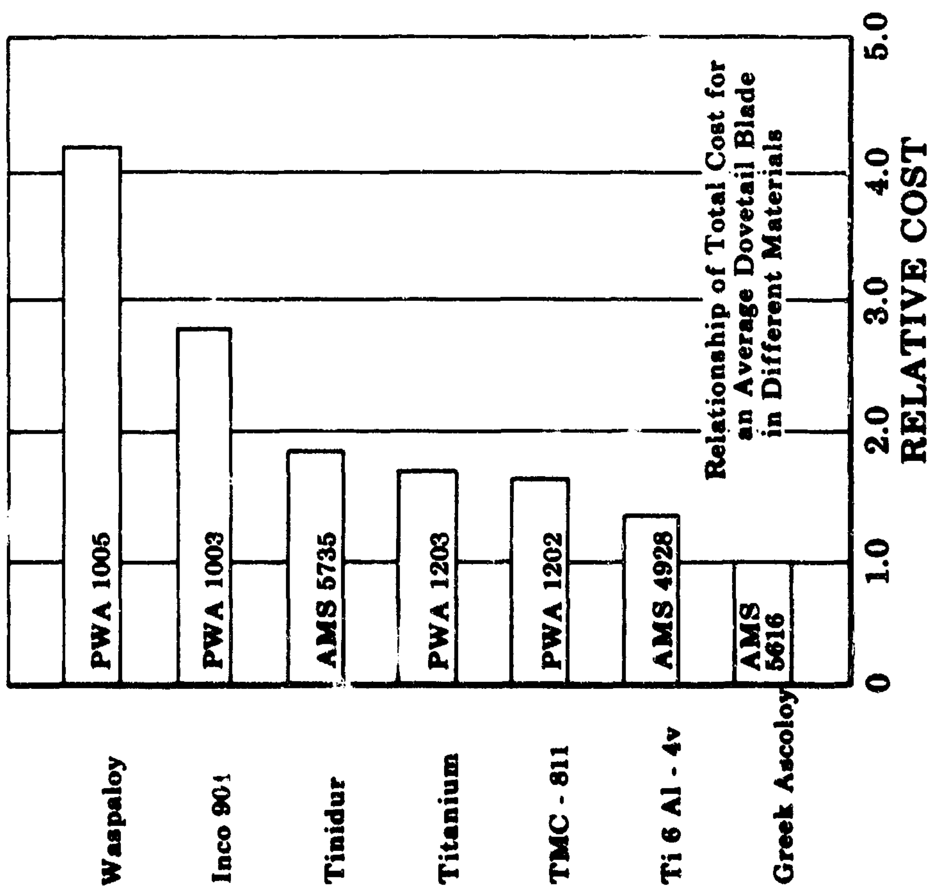


Figure 5 Compressor Blade Cost vs Material FD 16322

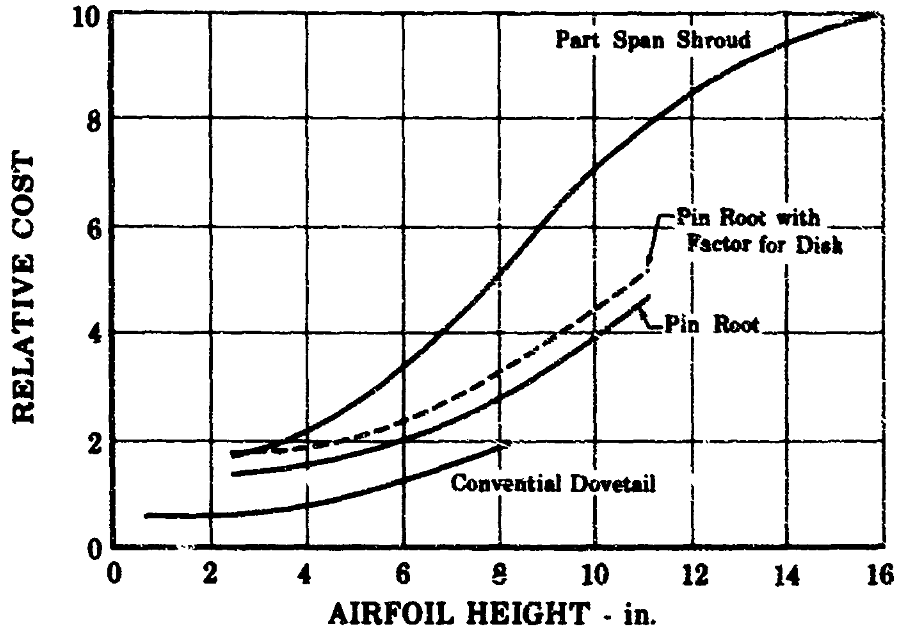


Figure 7. Compressor Blade Cost vs Root Configuration FD 16326

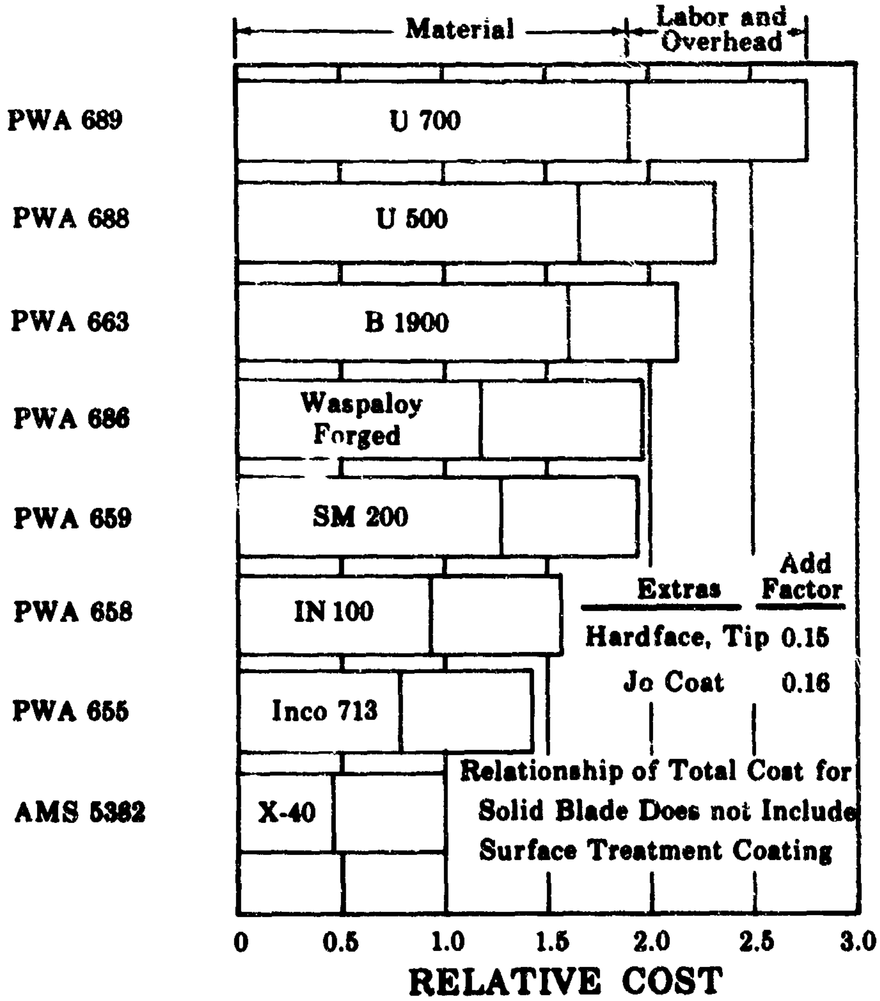


Figure 8. Turbine Blade Cost vs Material FD 16325

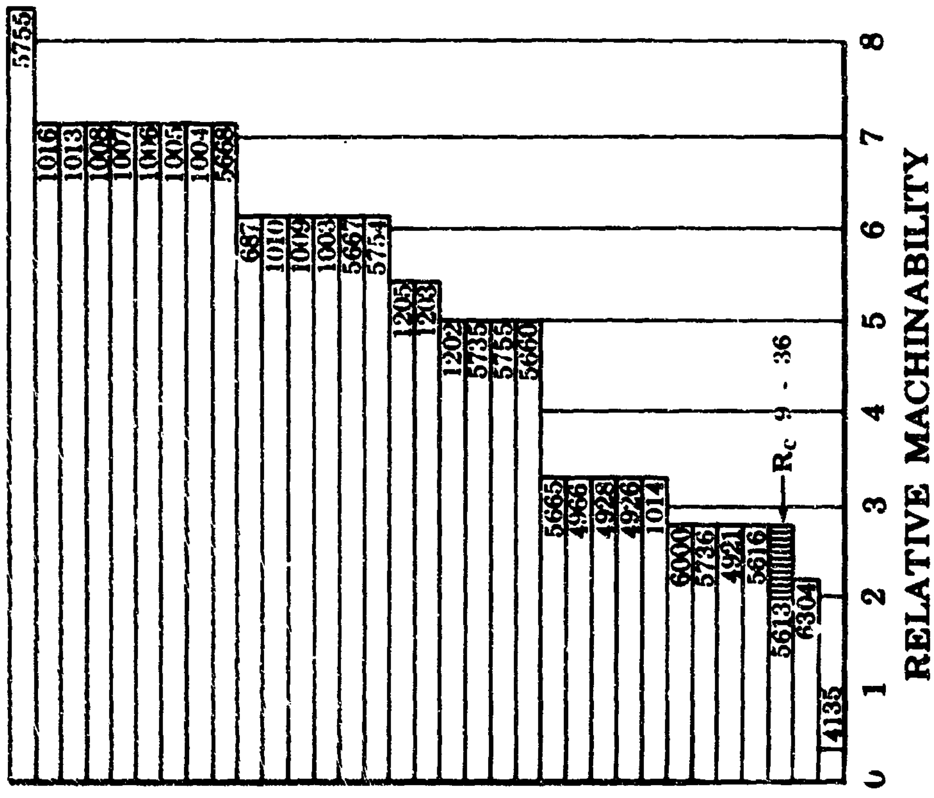


Figure 10. Relative Machinability of Various Materials (Turning) FD 16327

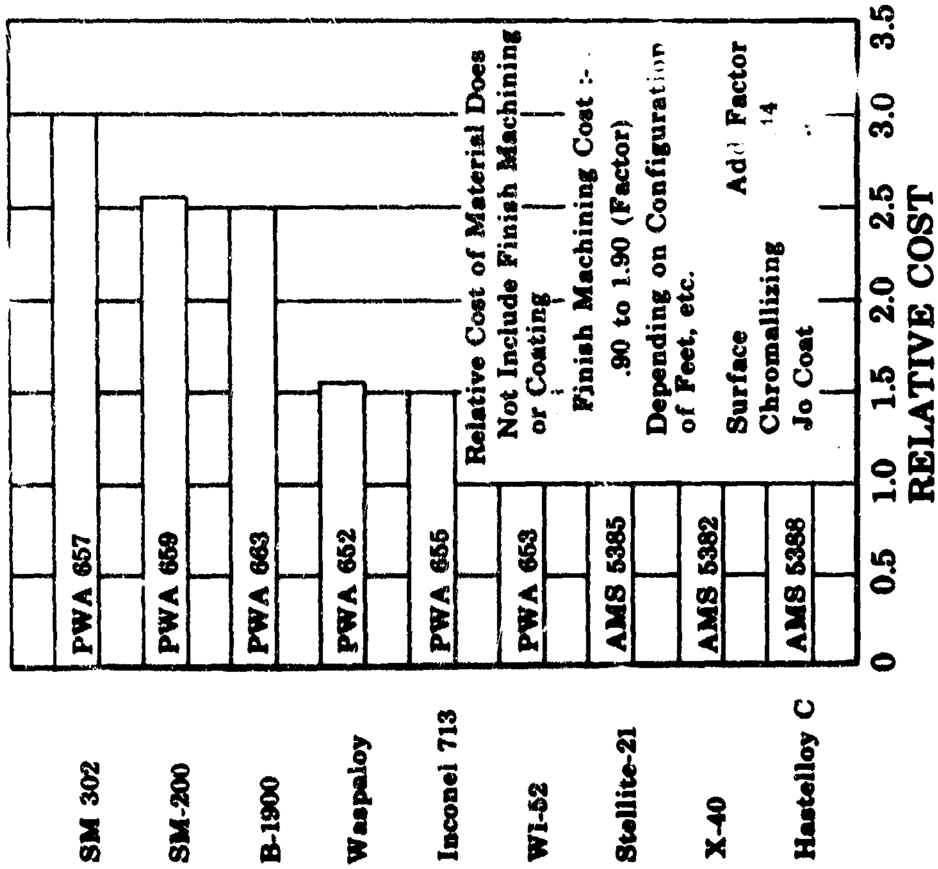


Figure 9. Turbine Vane Cost vs Material FD 16324

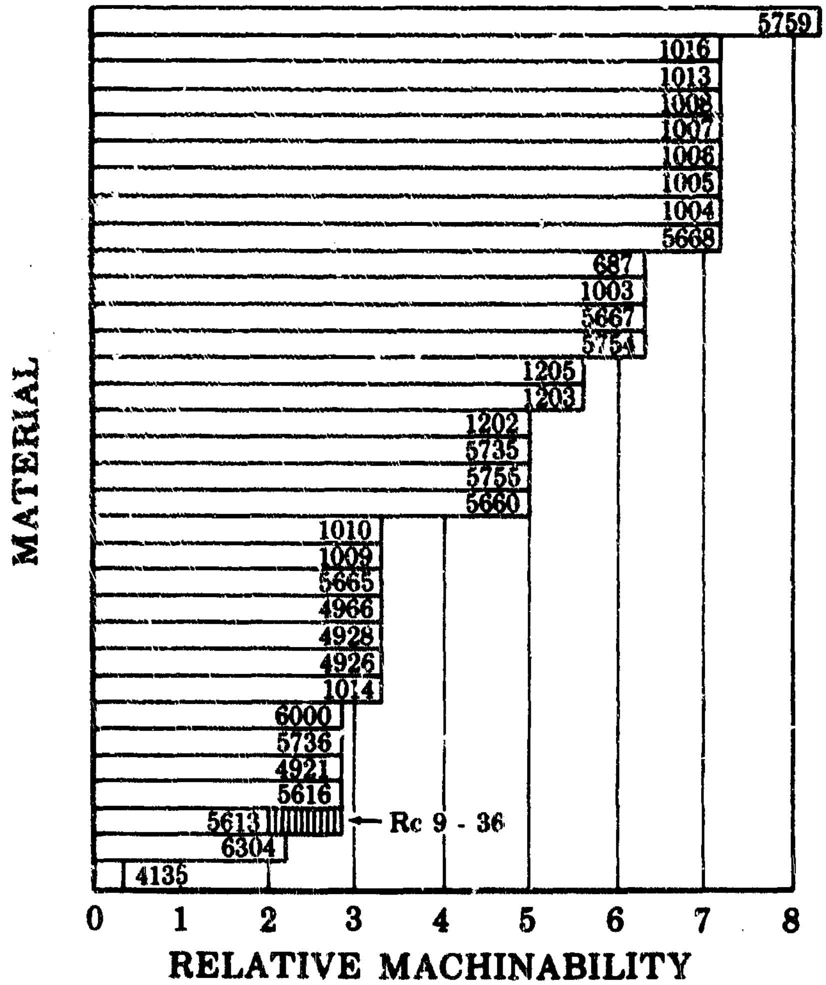


Figure 11. Relative Machinability of Various Materials (Drilling and Reaming) FD 16328

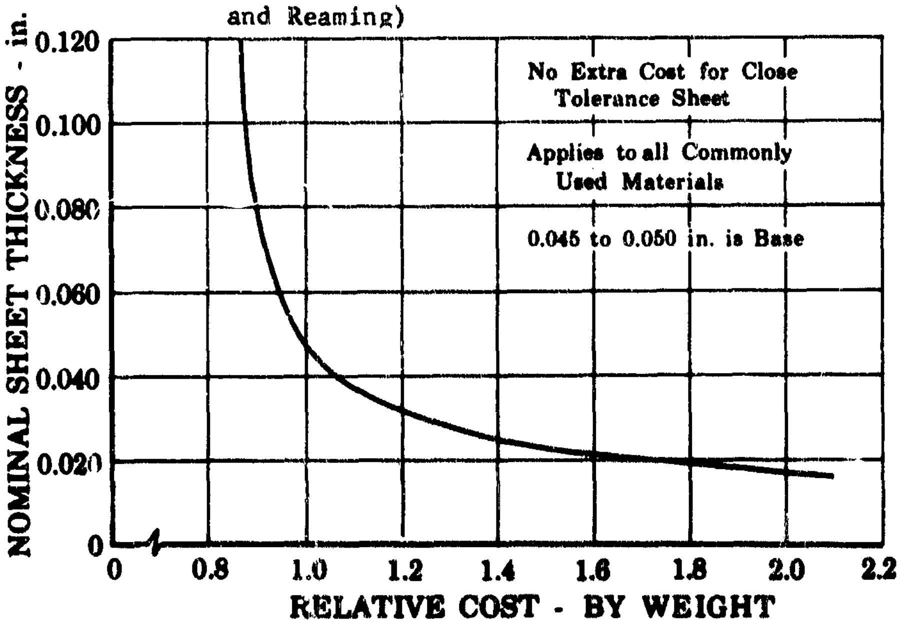


Figure 12. Sheet Metal Thickness vs Relative Cost FD 16321

Table 1. Relative Weldability of Various Materials (Fusion, Resistance, Electron Beam)

Material	Mat'l Spec	Not Recommended	Poor	Fair	Good	Excellent
Inco 718	1009					X
Ti (Comm. Pure)	4921					X
A-110	4926					X
A-110	4966					X
Inconel	5665					X
Tinidur	5736					X
Nickel 200	6000					X
Waspaloy	687				X	
Waspaloy	1004				X	
Waspaloy	1005				X	
Waspaloy	1007				X	
Inco 718	1010				X	
Ti (TMC-811)	1202				X	
410	5613				X	
Greek Ascoloy	5616				X	
Inconel X	5667				X	
Inconel X	5668				X	
Tinidur	5735				X	
Hastelloy X	5754			X		
TD Nickel	1014	X*				
Nickel 200	6000					X
Inco 718	1009				X	
Inco 718	1010				X	
Ti (TMC-811)	1202				X	
Ti (Comm. Pure)	4921				X	
A-110	4926				X	
A-110	4966				X	
410	5613				X	
Inconel	5665				X	
Inconel X	5667				X	
Inconel X	5668				X	
Waspaloy	687			X		

Material	Mat'l Spec	Not Recommended	Poor	Fair	Good	Excellent
Ti (TMC-811)	1202					X
Ti (Comm. Pure)	4921					X
A-110	4926					X
A-110	4966					X
410	5613					X
Greek Ascoloy	5616					X
Inconel	5665					X
Inconel X	5667					X
Nickel 200	6000					X
Inco 718	1009				X	
Inco 718	1010				X	
Inconel X	5668				X	
Hastelloy X	5754				X	
L-605	5759				X	
Waspaloy	687			X		
Tinidur	5736			X		
Waspaloy	1004		X			
Waspaloy	1005		X			
Waspaloy	1007		X			
Tinidur	5735	X**				
Greek Ascoloy	5616			X		
Tinidur	5736			X		
Hastelloy X	5754			X		
L-605	5759			X		
Waspaloy	1004		X			
Waspaloy	1005		X			
Waspaloy	1007		X			
Tinidur	5735	X**				
TD Nickel	1014	X*				

*Not recommended, but can be joined
**Weld as 5736 and heat-treat to 5735

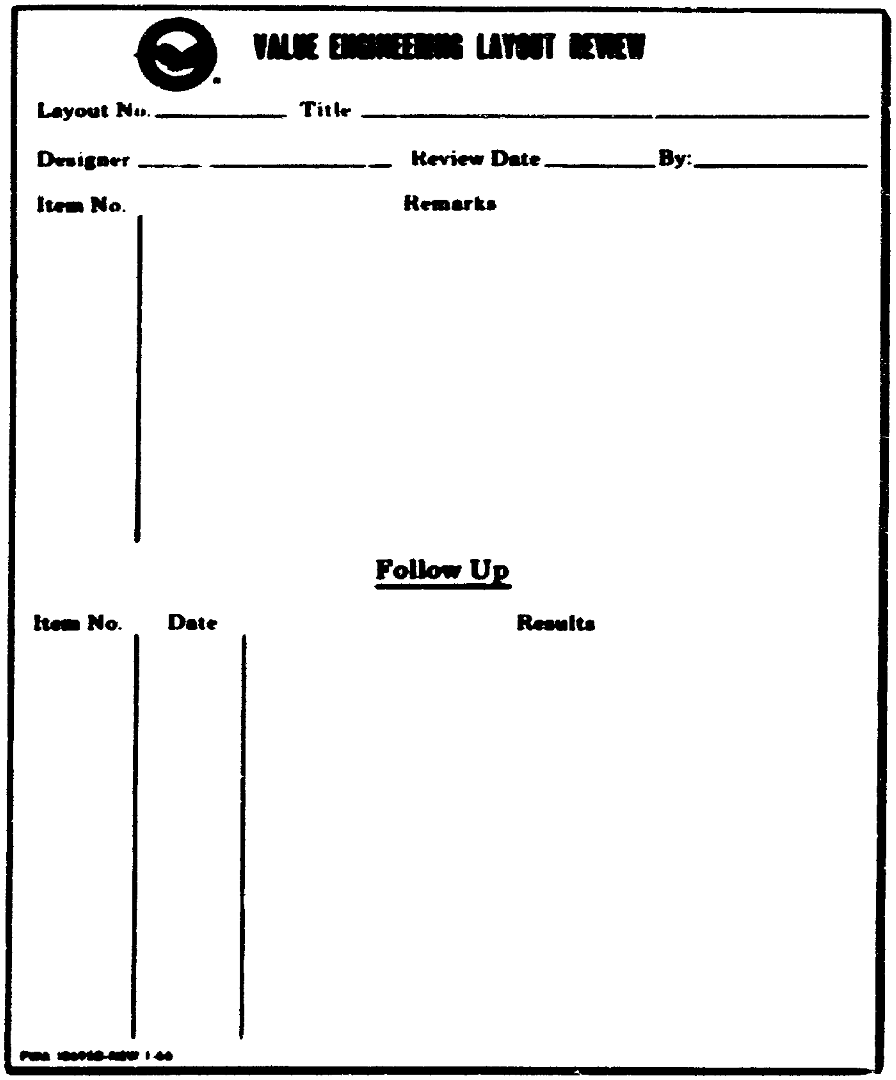


Figure 13. Value Engineering Layout Review

FD 17543

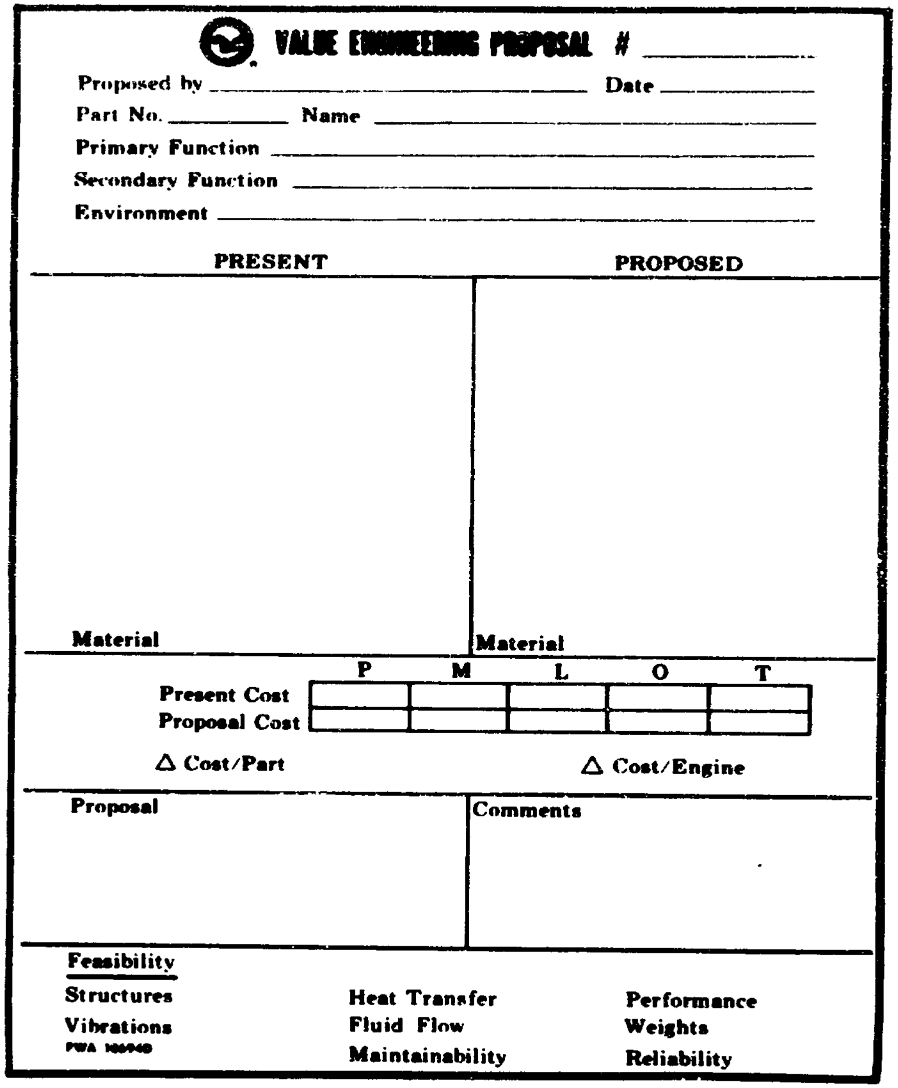


Figure 14. Value Engineering Proposal Form

VALUE ENGINEERING PROPOSAL # 1.03

Proposed by W. J. Tessmer   Date 1-11-66

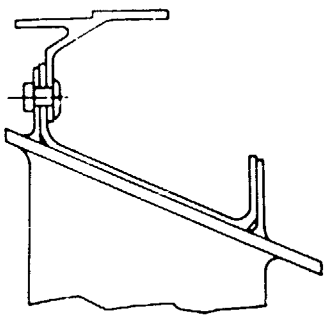
Part No [illegible]   Name 1st Stage Stator Inner Shroud

Primary Function Air Seal

Secondary Function

Environment [illegible]

PRESENT



Material AMS 5613

PROPOSED

Same Configuration

Material AMS 5504

	P	M	L	O	T
Present Cost		69.	13.	48.	130.
Proposal Cost		9.	6.	24.	36.

Δ Cost/Part 94.   Δ Cost/Engine 94.

Proposal Change the Material of the 1st-stage inner shroud from a forging to sheet metal.

Comments

Feasibility

Structures	Heat Transfer	Performance
Vibrations PWA 10694D	Fluid Flow	Weights
	Maintainability	Reliability

Figure 15. Value Engineering Proposal Form 1.03   FD 16316

VALUE ENGINEERING PROPOSAL # 1.07

Proposed by W. J. Tessmer   Date 6-23-66

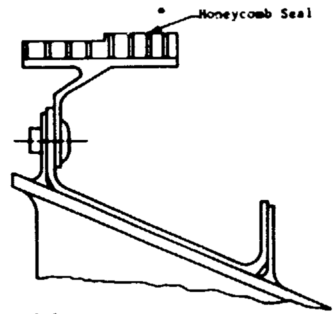
Part No. 2115112   Name 1st-Stage Inner Seal

Primary Function Air seal

Secondary Function

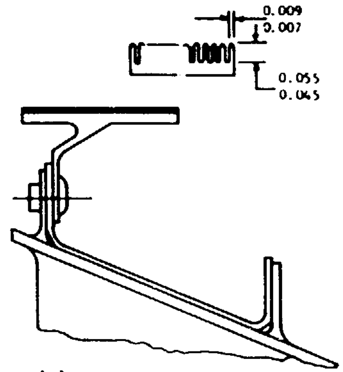
Environment Fan

PRESENT



Material AMS 5613

PROPOSED



Material AMS 5613

	P	M	L	O	T
Present Cost	368.				368.
Proposal Cost		61.	16.	63.	141.

Δ Cost/Part 227.   Δ Cost/Engine 227.

Proposal Serrated ring seal in place of honeycomb seal in the 1st-stage.

Comments Serrated type seals are in the JT14C high compressor.

Feasibility

Structures	Heat Transfer	Performance
Vibrations PWA 10694D	Fluid Flow	Weights
	Maintainability	Reliability

Figure 16. Value Engineering Proposal Form 1.07   FD 16315

VALUE ENGINEERING PROPOSAL # 1.09 Revised

Proposed by E.R. Earnest & J.W. Hughes Date 21 July 1966

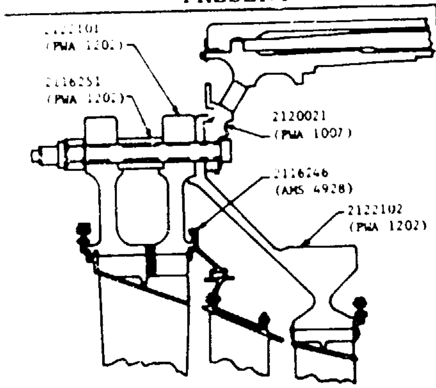
Part No [illegible] Name Fan Rotor

Primary Function Increase compressor inlet pressure

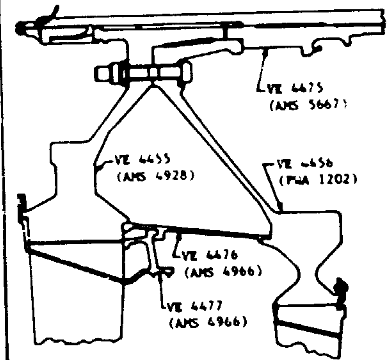
Secondary Function

Environment Air at [illegible]

PRESENT



PROPOSED



Material

Material

	P	M	L	O	T
Present Cost	-	5543.	863.	3241.	9647.
Proposal Cost	-	5027.	634.00	2375.	8036.

Δ Cost/Part 1611. Δ Cost/Engine 1611.

Proposal Replace 1st-stage disk and front hub with 1st-stage integral disk and hub.

Comments

Feasibility

Structures	Heat Transfer	Performance
Vibrations	Fluid Flow	Weights
PWA 10694D	Maintainability	Reliability

Figure 17. Value Engineering Proposal Form 1.09 FD 16944

VALUE ENGINEERING PROPOSAL # 2.01

Proposed by H. S. Buckhout Date 6-22-66

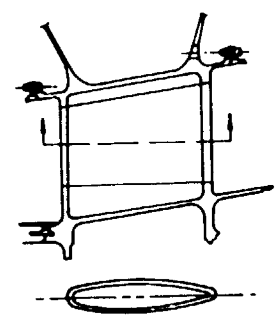
Part No. 2114798 2114799 Name Vane Intermediate Case

Primary Function Support Structure

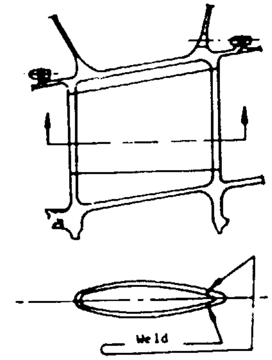
Secondary Function Direct Airflow

Environment Fan Discharge Air with Metal Temp to 640°F

PRESENT



PROPOSED



Material AMS 4966 Forging

Material AMS 4910 Sheet Metal

	P	M	L	O	T
Present Cost		166.	49.	182.	397.
Proposal Cost		40.	12.	45.	96.

Δ Cost/Part 301. Δ Cost/Engine 2410.

Proposal Substitute fabricated sheet metal vanes for vanes made from fully machined forgings.

Comments The engine configuration having the gas generator supported at the diffuser case should greatly reduce stresses in this area.

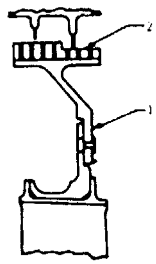
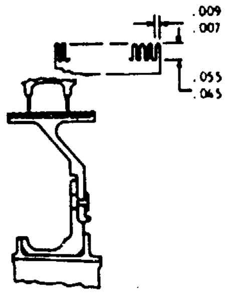
Feasibility

Structures	Heat Transfer	Performance
Vibrations	Fluid Flow	Weights
PWA 10694D	Maintainability	Reliability

Figure 18. Value Engineering Proposal Form 2.01 FD 16460

VALUE ENGINEERING PROPOSAL # 3.05 [illegible]

Proposed by [illegible] Date 10-25-66
Part No. [illegible] Name Compressor Case and Stators
Primary Function Air Seal
Secondary Function Inner Vane Support
Environment High Compressor

PRESENT	PROPOSED
	
Material 1-Hastelloy X 2-Inconel Honeycomb	Material Inconel

	P	M	L	O	T
Present Cost	750.				750.
Proposal Cost		550.	5.	20.	575.

Δ Cost/Part - 175.   Δ Cost/Engine - 875.

Proposal Serrated ring seals in place of Honeycomb in the 3rd to 7th stages, and change material from Hastelloy X to Inconel

Comments Serrated type seals are in the JTF-14C high compressor.

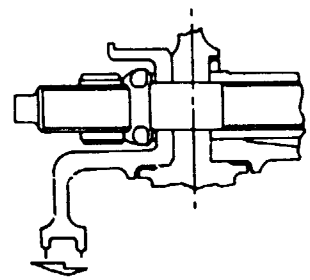
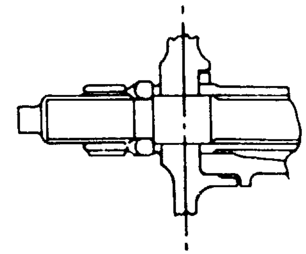
Feasibility
Structures
Vibrations
Heat Transfer
Fluid Flow
Maintainability
Performance
Weights
Reliability

PWA 10694D

Figure 19. Value Engineering Proposal Form 3.05   FD 16314

VALUE ENGINEERING PROPOSAL # 3.07

Proposed by J. J. Hughes Date 2-10-66
Part No. 2117794 Name High Compressor Front Air Seal
Primary Function Provide Bleed Flow Orifice for Brg Cooling Air
Secondary Function
Environment Air with Metal Temp to 800°F

PRESENT	PROPOSED
	
Material PWA 1013	Material

	P	M	L	O	T
Present Cost		4800.	159.	596.	5555.
Proposal Cost					000.

Δ Cost/Part 5555.   Δ Cost/Engine 5555.

Proposal Remove Front Air Seal

Comments Orifice can be incorporated in shaft spacer at compressor bleed station. 15-lb reduction in engine weight.

Feasibility
Structures
Vibrations
Heat Transfer
Fluid Flow
Maintainability
Performance
Weights
Reliability

PWA 10694D

Figure 20. Value Engineering Proposal Form 3.07   FD 16313

VALUE ENGINEERING PROPOSAL # 3.09

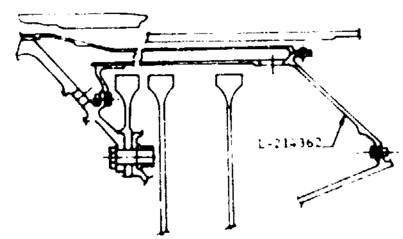
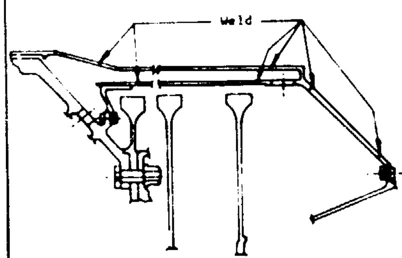
Proposed by W. T. Tessmer and G. Teddy Date 6-16-66

Part No [illegible] Name [illegible]

Primary Function [illegible]

Secondary Function

Environment High Compressor

PRESENT	PROPOSED
	
Material Inco 901	Material Inco 718

	P	M	L	O	T
Present Cost		920.	70	260.	1240.
Proposal Cost		310.	45.	170.	525.

Δ Cost/Part 715. Δ Cost/Engine 715.

Proposal Change bore tube from two machined forgings to a weldment.

Comments

Feasibility

Structures Heat Transfer Performance
Vibrations Fluid Flow Weights
PWA 106940 Maintainability Reliability

Figure 21. Value Engineering Proposal Form 3.09 FD 17299

VALUE ENGINEERING PROPOSAL # [illegible]

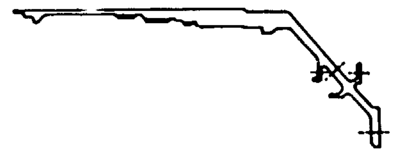
Proposed by W. T. Tessmer and G. Teddy Date [illegible]

Part No. [illegible] Name Front High Compressor Hub

Primary Function Support High Compressor Rotor

Secondary Function

Environment High Compressor

PRESENT	PROPOSED
	Same Configuration
Material PWA 1016	Material PWA 1003

	P	M	L	O	T
Present Cost		2310.	194.	[illegible]	[illegible]
Proposal Cost		1275.	175.	655.	2105.

Δ Cost/Part 1120. Δ Cost/Engine [illegible]

Proposal
Change front high compressor hub material from PWA 1016 to PWA 1003

Comments

Feasibility

Structures Heat Transfer Performance
Vibrations Fluid Flow Weights
PWA 106940 Maintainability Reliability

Figure 22. Value Engineering Proposal Form 3.10 FD 16346

VALUE ENGINEERING PROPOSAL # 5.01 (JT12A-20)

Proposed by ___ Date 1-11-66

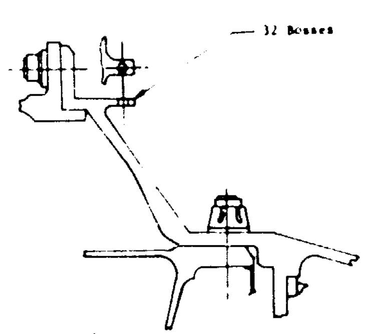
Part No ___ Name First Turbine Vane Inner Shroud

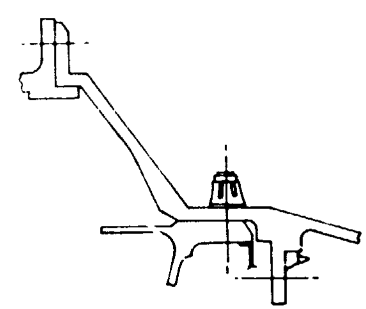
Primary Function Vane Fixed

Secondary Function Lock Wire Bosses

Environment Turbine Gas Metal Temp to 1100 F

PRESENT | PROPOSED





Material PWA 1004 | Material PWA 1004

	P	M	L	O	T
Present Cost		1300.	177.	670.	2147.
Proposal Cost		1300.	156.	591.	2017.

Δ Cost/Part 130. Δ Cost/Engine 130.

Proposal Remove lock wire bosses and wire bolts to one another.

Comments Some assembly difficulty may be encountered because of space limitations.

Feasibility

Structures | Heat Transfer | Performance
Vibrations PWA 106940 | Fluid Flow | Weights
| Maintainability | Reliability

Figure 23. Value Engineering Proposal Form 5.01 FD 16459

VALUE ENGINEERING PROPOSAL # 5.16 Revised

Proposed by J. W. Hughes Date 6-6-66

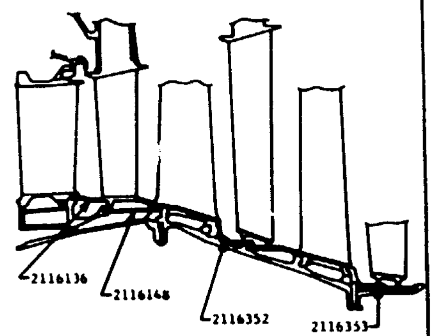
Part No. 2116136, 2116148, 2116352, 2116353 Name Ring Segments - Turbine Air Seal

Primary Function Turbine Blade Tip Seal

Secondary Function Form Turbine OD Flow Path

Environment Burner Exhaust Gas

PRESENT | PROPOSED



Same Configuration

Material PWA 1004 | Material AMS 5754

	P	M	L	O	T
Present Cost		2271.	372.	1395.	4038.
Proposal Cost		1202.	372.	1395.	2969.

Δ Cost/Part 1069. Δ Cost/Engine 1069.

Proposal For the subject seal segments, change material from PWA 1004 to AMS 5754.

Comments

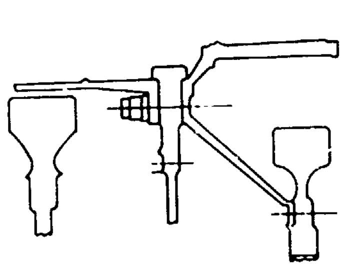
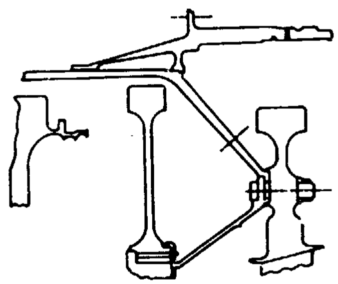
Feasibility

Structures | Heat Transfer | Performance
Vibrations PWA 106940 | Fluid Flow | Weights
| Maintainability | Reliability

Figure 24. Value Engineering Proposal Form 5.16 FD 16312

VALUE ENGINEERING PROPOSAL # 5.17 Revised

Proposed by W. J. Tessmer Date 6-23-66
Part No. 2120023 / 2120025 Name Shaft-Low Turbine
Primary Function Fan Drive
Secondary Function
Environment Turbine Gas with metal temp to 1120°F

PRESENT	PROPOSED
	
Material PWA 1007	Material 1003

	P	M	L	O	T
Present Cost		11,464.	632.	2360.	14,464.
Proposal Cost		7300.	480.	1800.	9580.

Δ Cost/Part 4884 Δ Cost/Engine 4884.

Proposal Substitute Inco 901 for Waspaloy in the low turbine shaft and make integral with hub.

Comments

Feasibility

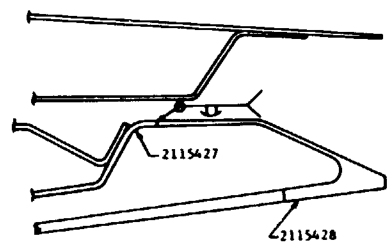
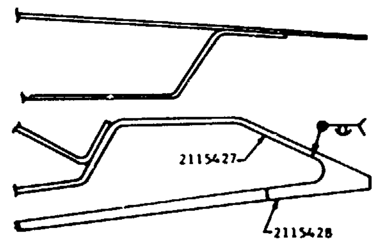
Structures	Heat Transfer	Performance
Vibrations	Fluid Flow	Weights
	Maintainability	Reliability

PWA 10694D

Figure 25. Value Engineering Proposal Form 5.17 FD 16461

VALUE ENGINEERING PROPOSAL # 6.04 Revised

Proposed by W. J. Tessmer Date 3/11/66
Part No. 2115425 Name Nozzle Duct Heater Assembly
Primary Function Flow Control
Secondary Function
Environment Burner discharge gas with metal temp to 1500°F

PRESENT	PROPOSED
	
Material L-605 and Hastelloy X	Material L-605 and Hastelloy X

	P	M	L	O	T
Present Cost		270.	45.	172.	487.
Proposal Cost		200.	39.	146.	385.

Δ Cost/Part 102. Δ Cost/Engine 102.

Proposal In the duct heater inner nozzle assembly reduce the size of nozzle end support forging (2115428) by increasing the length of the sheet metal part (2115427).

Comments

Feasibility

Structures	Heat Transfer	Performance
Vibrations	Fluid Flow	Weights
	Maintainability	Reliability

PWA 10694D

Figure 26. Value Engineering Proposal Form 6.04 FD 16311

VALUE ENGINEERING PROPOSAL # 6.05

Proposed by Project Engineering Date 5-5-66

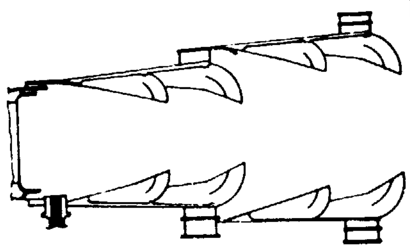
Part No. Name Duct Heater

Primary Function Augmentation

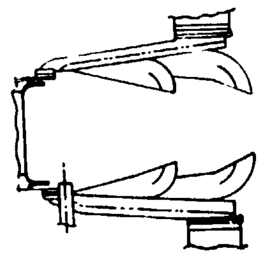
Secondary Function

Environment Burner gas with metal temp to 1400°F

PRESENT



PROPOSED



Material

Material

	P	M	L	O	T
Present Cost		4640.	5000.	18,700.	28,340.
Proposal Cost		3800.	3900.	14,600.	22,300.

Δ Cost/Part 6040.

Δ Cost/Engine 6040.

Proposal Shorten duct heater by 6 inches

Comments Saves 65 pounds

Feasibility
Structures
Vibrations
PWA 10694D

Heat Transfer
Fluid Flow
Maintainability

Performance
Weights
Reliability

Figure 27. Value Engineering Proposal Form 6.05

FD 16458

VALUE ENGINEERING PROPOSAL # 7.07

Proposed by W. J. Tessmer Date 30 June 1966

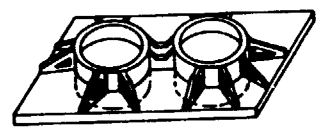
Part No. 2122503 Name Housing Thrust Reverser Deflector Bearing

Primary Function Bearing Housing

Secondary Function

Environment Reverser-Suppressor

PRESENT



PROPOSED

Same Configuration

Material AMS 4928 Titanium

Material Cast Titanium 6AC-4C

	P	M	L	O	T
Present Cost		$471.00	$102.00	$382.00	$955.00
Proposal Cost		$440.00	$ 56.00	$210.00	$706.00

Δ Cost/Part $250.00

Δ Cost/Engine $500.00

Proposal
Change hub material from forged titanium to cast titanium.

Comments

Feasibility
Structures
Vibrations
PWA 10694D

Heat Transfer
Fluid Flow
Maintainability

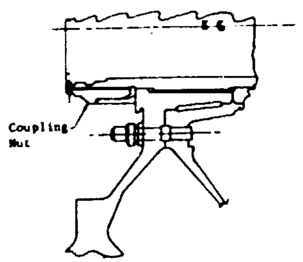
Performance
Weights
Reliability

Figure 28. Value Engineering Proposal Form 7.07

FD 16943

VALUE ENGINEERING PROPOSAL # 1.04A

Proposed by W. J. Tessmer Date 6-23-66
Part No. L-214362 Name Fan Coupling
Primary Function Retain Fan Rotor
Secondary Function
Environment Air to 600°F

PRESENT	PROPOSED
	Same Configuration
Material Inco 718	Material AMS 6415

	P	M	L	O	T
Present Cost					
Proposal Cost					

Δ Cost/Part 50. Δ Cost/Engine 50.

Proposal Change material of fan coupling from Inco 718 to AMS 6415

Comments AMS 6415 needs to be plated.

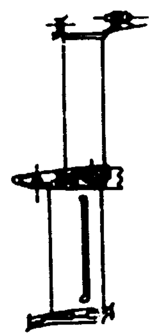
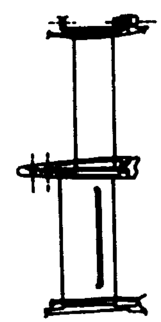
Feasibility

Structures Heat Transfer Performance
Vibrations Fluid Flow Weights
PWA 106940 Maintainability Reliability

Figure 29. Value Engineering Proposal Form 1.04A FD 16456

VALUE ENGINEERING PROPOSAL # 1.08 Revised

Proposed by W. J. Tessmer Date 6-23-66
Part No. 2120038 Name 2nd-Stage Stators and Duct Exit Guide Vanes
Primary Function Guides airflow to compressor and duct
Secondary Function
Environment Air to 650°F

PRESENT	PROPOSED
	
Material PWA 1202	Material PWA 1206

	P	M	L	O	T
Present Cost	6160.				6160.
Proposal Cost		1155.	160.	585.	1900.

Δ Cost/Part Δ Cost/Engine 4260.

Proposal Use strip stock in place of forged 2nd stators and duct exit guide vanes

Comments

Feasibility

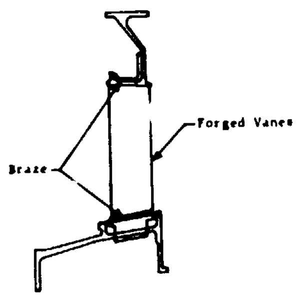
Structures Heat Transfer Performance
Vibrations Fluid Flow Weights
PWA 106940 Maintainability Reliability

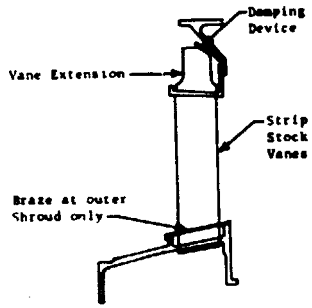
Figure 30. Value Engineering Proposal Form 1.08 FD 16945

VALUE ENGINEERING PROPOSAL # 3.04A Revised

Proposed by H. J. Rubel and J. P. McSwiney Date 3-23-66
Part No. 2120013 Name Vane and Case Assemblies 5th, 6th & 7th stages
Primary Function To direct airflow
Secondary Function
Environment Air with metal temp to 1000 F

PRESENT	PROPOSED





Material | Material

	P	M	L	O	T
Present Cost	7153.				7153.
Proposal Cost		1390.	66.	247.	1703.

△ Cost/Part △ Cost/Engine 5450.

Proposal Substitute damped strip stock vanes for forged vanes in the 5th,6th & 7th vane and case assemblies. Damping the vanes should alleviate the structural problems normally associated with brazed strip stock stator construction.

Comments Test data required prior to incorporation.

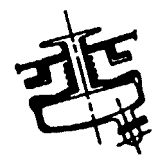
Feasibility
Structures
Vibrations
PWA 10694D
Heat Transfer
Fluid Flow
Maintainability
Performance
Weights
Reliability

Figure 31. Value Engineering Proposal Form 3.04A FD 16308

VALUE ENGINEERING PROPOSAL # 3.12

Proposed by C. Leddy and W. Tessmer Date 7-13-66
Part No. L-212621-1 Name Starting Bleed Valves
Primary Function Bleed Air During Start
Secondary Function
Environment High Compressor

PRESENT	PROPOSED



Same Configuration

Material AMS 5382 (Cast Stellite 31) | Material Cast 347

	P	M	L	O	T
Present Cost	90.				90.
Proposal Cost	60.				60.

△ Cost/Part 30. △ Cost/Engine 180.

Proposal Change material of start bleed valve housings.

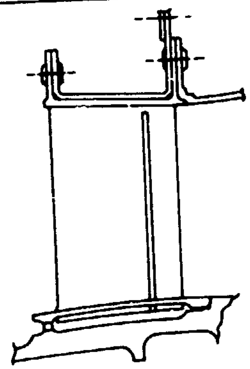
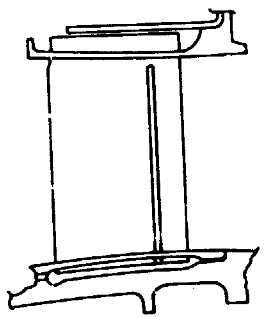
Comments Relocation to the compressor section provides a cooler environment. Saves approximately 1.8 lb/engine weight due to lower density material.

Feasibility
Structures
Vibrations
PWA 10694D
Heat Transfer
Fluid Flow
Maintainability
Performance
Weights
Reliability

Figure 32. Value Engineering Proposal Form 3.12 FD 16942

VALUE ENGINEERING PROPOSAL # 3.14

Proposed by W. J. Tessmer Date 6-23-66
Part No. L-214362 Name High Compressor Exit Guide Vanes
Primary Function Guide air into burner
Secondary Function
Environment Air to 1100 F

PRESENT	PROPOSED
	
Material Inco 718	Material Inco 625

	P	M	L	O	T
Present Cost	3030.				3030.
Proposal Cost	1530.				1530.

Δ Cost/Part 1500. Δ Cost/Engine 1500.

Proposal Change forged Inco 718 EGV to Inco 625 strip stock

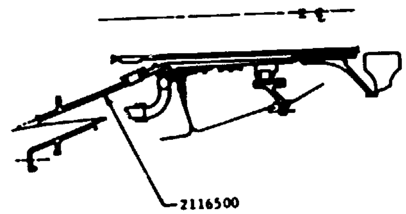
Comments

Feasibility
Structures
Vibrations PWA 106940
Heat Transfer
Fluid Flow
Maintainability
Performance
Weights
Reliability

Figure 33 Value Engineering Proposal Form 3.14 FD 16868

VALUE ENGINEERING PROPOSAL # 5.05

Proposed by W. J. Tessmer and G. Leddy Date 10-2-66
Part No. 2116500 Name High Rotor Shaft
Primary Function Torque Transmission
Secondary Function
Environment Air with metal temp to 1100°F

PRESENT	PROPOSED
	Same Configuration
Material PWA 1006	Material PWA 1003

	P	M	L	O	T
Present Cost		5315.	382.	1435.	7132.
Proposal Cost		2950.	382.	1435.	4767.

Δ Cost/Part 2365. Δ Cost/Engine 2365.

Proposal Substitute PWA 1003 for PWA 1006 as rotor shaft material.

Comments

Feasibility
Structures
Vibrations PWA 106940
Heat Transfer
Fluid Flow
Maintainability
Performance
Weights
Reliability

Figure 34. Value Engineering Proposal Form 5.05 FD 16307

VALUE ENGINEERING PROPOSAL # 5.

Proposed by [illegible] Date 2-10-66

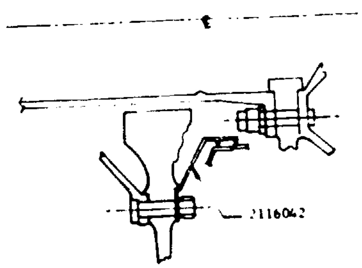
Part No. 2116042 Name Turbine Air Seal

Primary Function Prevent Recirculation Leakage Around Stator

Secondary Function

Environment Turbine Gas with Metal Temp to 1100°F

PRESENT



Material PWA 1007

PROPOSED

Same Configuration

Material PWA 1003

	P	M	L	O	T
Present Cost		406.	37.	138.	581.
Proposal Cost		260.	37.	138.	435.

Δ Cost/Part 146. Δ Cost/Engine 146.

Proposal Substitute PWA 1003 for PWA 1007 as air seal material.

Comments

Feasibility
Structures
Vibrations PWA 106940
Heat Transfer
Fluid Flow
Maintainability
Performance
Weights
Reliability

Figure 35. Value Engineering Proposal Form 5.06 FD 16306

VALUE ENGINEERING PROPOSAL # 5.20

Proposed by [illegible] Date 6-23-66

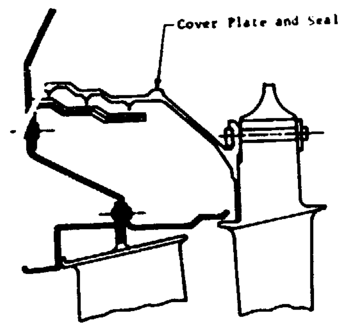
Part No. [illegible]-214362 Name 2nd-Stage Turbine Front Seal and Cover Plate

Primary Function Prevent Recirculation Flow Around Stator

Secondary Function

Environment Turbine Gas with Metal Temp to 1300 F

PRESENT



Material PWA 1007

PROPOSED

Same Configuration

Material PWA 1003

	P	M	L	O	T
sent Cost		864.	213.	800.	1875.
Proposal Cost		412.	213.	800.	1425.

Δ Cost/Part 450. Δ Cost/Engine 450.

Proposal Substitute PWA 1003 for PWA 1007 as plate and seal material.

Comments

Feasibility
Structures
Vibrations PWA 106940
Heat Transfer
Fluid Flow
Maintainability
Performance
Weights
Reliability

Figure 36. Value Engineering Proposal Form 5.20 FD 16457

SECTION V
STANDARDIZATION PROGRAM

A. STANDARDIZATION OBJECTIVES

The standardization program that Pratt & Whitney Aircraft will employ during the Phase III effort is designed to accomplish the following objectives. This program is an extension of the program used during Phase II-C, which contributed to the application of standardized parts, processes and procedures to the JTF17 engine program.

1. Improve Reliability

Engine reliability will be improved by use of standard hardware, materials, processes, practices, and configurations that have proved dependable through millions of hours of commercial and military service.

2. Improve Maintainability

Maintainability will be improved through the use of approved standards relating to engine design, fabrication, inspection, hardware, training, tools, maintenance, overhaul, and ground handling equipment. These standards will be used to achieve an optimum degree of interchangeability of parts and subassemblies.

3. Reduce Costs

Cost reductions will be realized by (1) use of standardized alloys, material sizes, manufacturing processes, and high-production hardware; (2) minimizing the number of sizes and types of items used in the engine; (3) utilization of nationally recognized standards of terminology, and (4) saving manpower by avoiding reinvestigations into areas where standards have already been established.

4. Assure Quality

Quality will be enhanced by (1) use of proved design practices, fabrication methods, inspection techniques, and test procedures; (2) continuous monitoring of review procedures to enforce the standardization effort; and (3) the use of standard tools and manufacturing procedures.

5. Promote Safety

Safety will be promoted by use of proved standards for engine and equipment design, and through Human Engineering studies.

B. ORGANIZATION - FUNCTIONS AND RESPONSIBILITIES

Standardization activities supporting Phase III of the SST program will be under the direction of the Standardization Engineer and administered by the Manager, JTF17 Product Assurance, reporting to the JTF17 Program Manager. The Manager, JTF17 Product Assurance, administers all JTF17 Safety, Standardization, Quality Assurance, Reliability, Maintainability, Human Engineering, and Value Engineering activities. By maintaining close liaison among all of these activities, the Manager will assure that maximum standardization efforts are applied to the JTF17 program. Standardization operating groups in each area take direction from the Standardization Engineer. Responsibilities are as indicated below.

1. Standardization Engineer Responsibilities

The Standardization Engineer coordinates individual departmental efforts through his representatives in each department and activities requiring particular attention to provide a successful overall Standardization Program. He will:

1. Define general policies of the Program Manager as they relate to Standardization.
2. Establish and disseminate policy on Standardization as related to other program interests.
3. Set realistic targets consistent with the objectives and requirements of the overall program. This involves development and evaluation of standardization research programs, review of high operational cost areas for standardized alternative programs, and studies of capability of personnel and equipment of meeting proposed goals.
4. Ensure interdepartmental cooperation in implementation of standardization requirements, such as dissemination by Purchasing and enforcement by Quality Assurance of Design standardization policies for subcontractor parts.
5. Continuously evaluate the status of the program.
6. Report progress or problem areas to program management.
7. Coordinate standardization efforts with division and corporation standardization program.
8. Ensure adequate training and indoctrination of personnel whose work involves standardization.

2. Standardization Operating Personnel

The responsibilities of the Standardization operating personnel in each department are described in the following paragraphs. Each department's Standardization Representative acts as a representative for the Standardization Engineer in the establishment, operation and review of the department's standardization activities, and performs liaison between the Standardization Engineer and other supervision in the department. He takes direction from the Standardization Engineer in matters pertaining to the JTF17 Program.

a. Design

Standardization responsibilities include control of standardization efforts pertaining to analytical and mechanical design, drafting, engineering records, engineering change control, parts lists, utility hardware, publications, and photographic engineering. Activities in this area are centered in the Design Standards department, reporting functionally through the Chief, Design Services, to Chief, Engine Design.

b. Quality Assurance

Standardization responsibilities include establishment and enforcement of standard manufacturing, assembly and test inspection requirements, quality review procedures, and quality assurance data requirements for drawings. These activities are centered in Quality Engineering, reporting functionally through the Quality Engineer to the Chief, Quality Assurance.

c. Manufacturing

Standardization responsibilities include establishment of standard policies for tool and gage design, tool and material procurement, manufacturing and process procedures, and assembly instructions and procedures. Departments performing these activities report functionally to the Chief, Manufacturing Operations.

d. Test

Standardization responsibilities include establishment of standardized requirements for procedures, instructions, instrumentation, data control systems, and test equipment. These efforts are centered in the Test Operations Departments which report functionally to the Chief, Test Operations.

e. Systems and Procedures

Standardization responsibilities include establishment of interdepartmental procedures ensuring the adherence of each department to program, division, and corporative management directives and policies. These standardization activities are centered in the Systems and Procedures group reporting functionally to the Controller.

f. Purchasing

Standardization responsibilities include informing subcontractors of Pratt & Whitney Aircraft standardization requirements, ascertaining subcontractor capabilities of compliance and selection of subcontractors who will comply with P&WA standardization requirements. Activities in these areas report functionally to the Purchasing Manager.

C. ACCOMPLISHMENT OF OBJECTIVES

1. Management and Implementation

It is this Contractor's long established practice to use Government and Industry standards and specifications, except where suitable Government or Industry documents are not available for an intended application. A Government or Industry standard is generally considered to be acceptable when it has been coordinated with the proper segment of industry such as MS four-digit aircraft engine standards that have been coordinated in the SAE Committees. P&WA participates in the establishment and control of these standards through representation on the SAE committees. Applicable Government and Industry Standards and Specifications will be employed throughout the design, development, production, and service of the JTF17 engine.

P&WA utilizes standardization manuals, specifications, procedures, and other publications to implement applicable Government, Industry, and P&WA standards. These standards are reviewed and approved by appropriate levels of management and are effective for new designs on the date of publication. They are accompanied, as applicable, with management directives establishing the status of the superseded standards so that maximum benefits occurring from standardization are realized.

Existing Pratt & Whitney Aircraft standards, including those standards developed under previous phases, and new standards that will be created under the JTF17 program, are subject to improvement and updating as Pratt & Whitney Aircraft's experience with these standards indicates. Each revision or addition to any Pratt & Whitney Aircraft Standards Manual or other standardization document will be reviewed and approved by an appropriate level of management as required by Standard Procedures and department policies.

2. Standardization Manuals and Specifications

All P&WA manuals, procedures, and specifications are generated with the considered objective of standardization. Primary emphasis on standardization is centered in the publications described below. The information contained in these publications enables management to actively promote the use of Pratt & Whitney Aircraft's experience, standard practices, and test-substantiated data in the JTF17 engine program. Sample pages from each of these publications are shown in figure 1.

a. Design Standards Publications

The Design Manual (DM) is a comprehensive guide for designers and provides to each designer P&WA's design and test experience on a wide variety of subjects including standard manufacturing processes, strength considerations, sources of information, and engine components. A typical DM presentation for engine components such as gears, seals, flanges, rotating parts and bearings includes the following:

1. General - P&WA policies and scope of the subject
2. Terminology - Symbols and definitions

3. Types of the Component Normally Employed - Technical information, normal applications, limitations, advantages, and disadvantages of each type
4. Methods of Calculations - Design factors of safety, reflected through equations, curves, tables, figures, and computer programs available at P&WA
5. Standardization Requirements - Design, material, and processing specifications; inspection test required; and allowances that must be provided for fabrication, inspection, installation, test, and service.
6. Designer's Responsibilities - Requirements for designers to incorporate standard practices into designs.
7. Other Sources of Information - Cross-reference to Government, industry, and other P&WA manuals and publications that contain information on the subject.

The Drafting Room Manual (DRM) establishes standardized drafting practices and eliminates duplication by establishing standard terminology, codes, and drafting practices that are employed by divisional drawing activities. Some of the subjects included in this manual are:

1. General Drafting P ctices
2. Types of Drawings
3. Dimensioning and Tolerancing
4. General Drawing Notes
5. Vendor Print Coordination
6. Drawing Release and Change Procedure
7. Preferred Material Sizes
8. Identification Marking
9. Heat Treatment
10. Surface Treatment

The Parts Selection Book (PSB) is a manual of utility standard parts including such items as seals, bolts, nuts, rivets, and bearings. The PSB contributes to P&WA's standardization program by disseminating appropriate Government-Industry coordinated standard utility parts information and lists other items of a utility nature with which P&WA has had satisfactory experience. The PSB is available to Engineering, Manufacturing, Test and Service personnel to minimize the number of kinds and sizes of parts and equipment which will be required in the JTF17 Engine Program.

The Design Standards department prepares and controls the Design Manual, Drafting Room Manual, and Parts Selection Book. Efforts of this department are fully coordinated with and supported by Program. Design and Drafting supervision. Continuously updated design standardization information is created, reviewed by the above supervision, and made available to the JTF17 Engine Program Designers and Draftsmen along with instructions that this information be used to maximum practicable extent in each new design and drawing. To facilitate the monitoring of standardization, design layouts and drawings are reviewed by specialized personnel as follows:

Layouts

Metallurgy Engineer	Value Engineer
Source Approval Representative	Design Project Engineer
Reliability Engineer	Chief Design Engineer
Maintainability Engineer	Project Engineer

Drawings

Design Analysis	Source Approval Representative
Metallurgy Engineer	Weights Group
Vendor Print Coordinator	Chief Draftsman

b. Materials Manual and Specifications Manuals

Standards that relate to appropriate Government and Industry specifications and P&WA specifications for (1) materials, and (2) chemical and metallurgical processing of these materials are maintained in the Materials Manual and in AMS and PWA Specifications Manuals issued by the P&WA Materials Engineering Group. SAE Aeronautical Materials Specifications (AMS) are selected, and Pratt & Whitney Aircraft material and processing specifications are initiated, selected or revised by Materials Engineering supervision.

All new P&WA design specifications that standardize design requirements, such as those covering drawing interpretation, riveting, threads, and surface finish, are initiated by Design Services subject to review by Materials Engineering. All of these specifications are referenced on P&WA drawings; therefore, all revisions are subject to the Engineering Change Procedure requiring approval of the Program Manager and other appropriate supervisory personnel as covered by Standard Procedures.

c. Quality Assurance Publications

Quality Engineering and Materials Engineering prepare and publish Quality Standards to provide acceptance limits for all chemical, physical, metallurgical, surface and subsurface conditions, and workmanship that affect the quality of materials, parts, or assemblies. The Quality Standards are used in conjunction with the designated AMS and Pratt & Whitney Aircraft Specifications and drawings.

Engine Quality Standards are coordinated with and approved by managers in Quality Assurance, Engine Design, and Materials Engineering.

The following types of Quality Standards are presently in regular use:

SFS - Surface Finish Standards
FPS - Fluorescent Penetrant Standards
STS - Surface Temper Standards
GSS - Grain Size Standards
EIS - Etch Inspection Standards
VIS - Visual Inspection Standards
SIS - Sonic Inspection Standards
DCS - Dimensional Control Standards
MPS - Magnetic Particle Standards
XRS - X-ray Standards

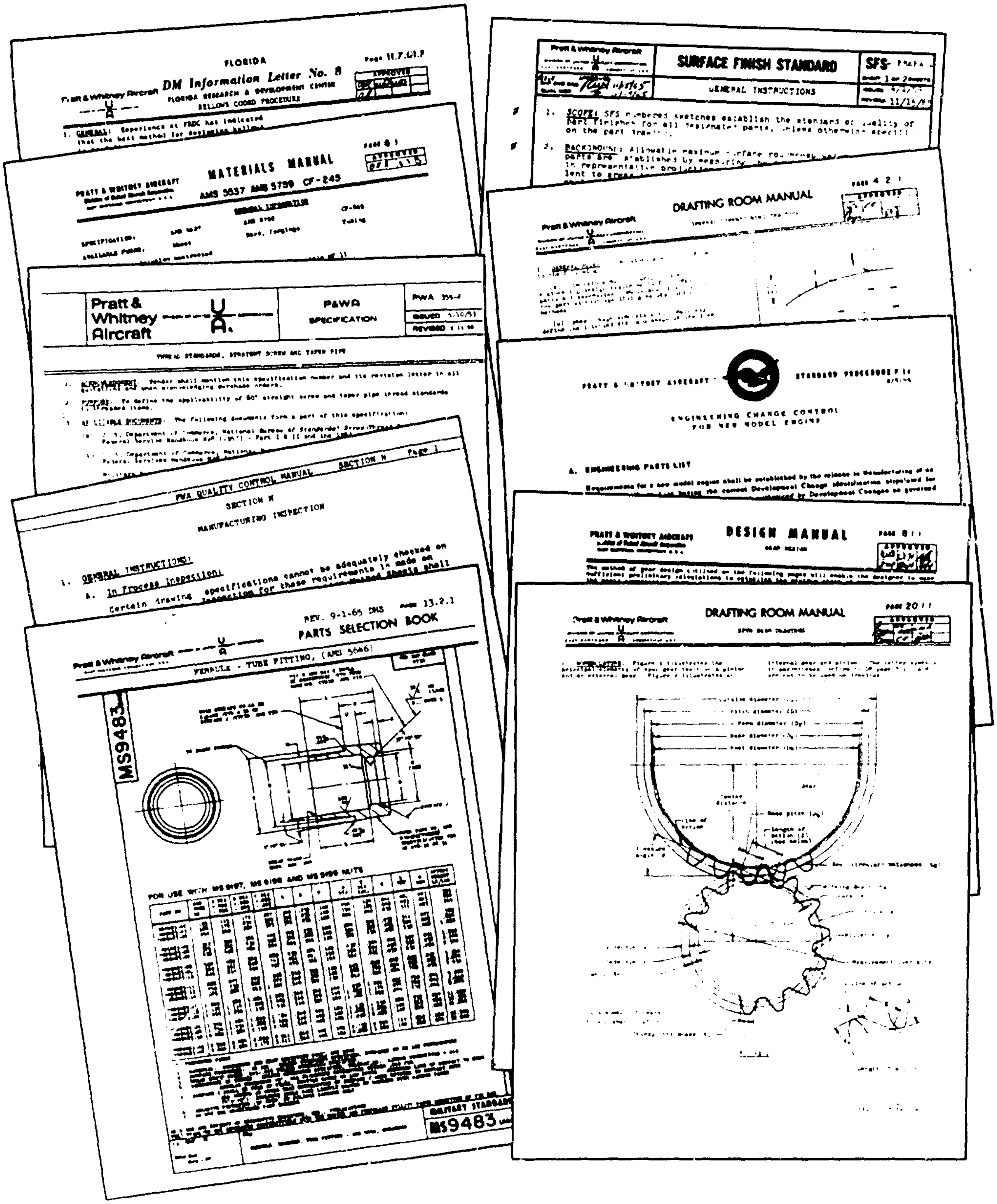


Figure 1. Sample Pages of the Design Manual, Drafting Room Manual, Parts Selection Book, and Pratt & Whitney Aircraft Specifications

FD 16565
FVC

d. Standard Procedures Manual

The Pratt & Whitney Aircraft Standard Procedures Manual is the primary vehicle used for dissemination of management standardization policies and directives across departmental lines to divisional activities including accounting, purchasing, sales and service, personnel, and engineering. New or revised Standard Procedures are prepared by the Systems and Procedures Group, approved by department heads, divisional management, or both, depending on the subject matter of the procedure or directive.

3. Subcontractor Standardization Control

The requirements for the JTF17 engine demand the most economical and reliable parts that can be produced. Therefore, maximum standardization of subcontractor-supplied parts, as well as those manufactured by P&WA, must be continuously assured. This standardization is accomplished through the joint efforts of the P&WA Engineering, Quality Assurance, Manufacturing, and Purchasing Departments.

Program Project Engineering and the Design Engineering Department initiate preliminary standardization requirements for subcontractors early in the design phase when the use of a subcontractor-designed part is indicated. This is accomplished in conjunction with the subcontractor and includes an exchange of prints, whereby P&WA's standards in the form of material, processing, and design specifications are coordinated with the subcontractor. These negotiated standardization requirements are then formally established by the Project and Design Engineering Departments, through an existing P&WA vendor print coordination system. Quality Control issues to the Purchasing Department all applicable standards that are not reflected on P&WA drawings, using inspection, laboratory, and engine test data, as well as past experience with similar parts. When the subcontractor is manufacturing a P&WA-designed part, complete information is provided by the Purchasing Department via P&WA-furnished drawings, specifications, and standards. Standardization is thus imposed directly on these parts, without the negotiation necessary for subcontractor designs.

Through the procedures outlined above, P&WA's subcontractor standardization practices are established by Engineering and Quality Control. These efforts are then formally transmitted via Purchase Orders by P&WA's Purchasing Department to the applicable subcontractors.

The responsibility of assuring that P&WA subcontractors are complying with the standards transmitted in the Purchase Order is a function of P&WA's Quality Control Department. Each new subcontractor is thoroughly investigated by the P&WA Purchasing Department and Quality Control to determine his financial status, plant facilities, capabilities of meeting production schedules, and effectiveness of his Quality Control in meeting P&WA standardization requirements. This is continuously assured through a P&WA Quality Control program at the subcontractor's facility or at P&WA, as applicable. When surveillance at the subcontractor's facility is determined to be the most effective method of assurance, a P&WA Quality Control Representative assures that the subcontractor is complying with applicable standards, procedures, and Purchase Order requirements. Vendor quality control supervision reports monthly on the effectiveness of each subcontractor's quality control program.

4. Employees' Standardization Training

A planned program of training Pratt & Whitney Aircraft's newly hired employees is conducted in the Training Section of the Personnel Department and will be used for the JTF17 engine program. Indoctrination lectures by both the Training Section and Supervisory Personnel of several Engineering and Manufacturing departments acquaint the new employee with Pratt & Whitney Aircraft's philosophies and procedures concerning standardization. These lectures, together with closely supervised on-the-job training and rotational work assignments, cover a period of six months for new design, test, and standards engineers. Other departments, such as Purchasing, provide additional departmental training programs to acquaint new employees with various aspects of standardization pertaining to their work. The subjects during the job break-in include standardization of drawing practices, manufacturing processes, and technical aspects of Pratt & Whitney Aircraft's products. The extent of an employee's training is keyed to the needs of his department's activities.

5. Standardization of Design Philosophy and Methods

Pratt & Whitney Aircraft Design Engineers review and apply all applicable proven concepts of earlier engines to new engine designs. Reviews and evaluations from other engineers in Project Engineering, Reliability, Maintainability, Value Engineering, Metallurgy, and Design Analysis, as well as the Design Project Engineer and Chief Design Engineer are also studied. Standardization efforts in the Design Engineering Department are keyed to the concept that the repeated usage, by Design, of a proven standard results in inclusion of the concept in an appropriate manual. Considerable proven design experience has been accumulated in previous engine programs, including the J58 and the Phase II-C JTF17 initial test engines, and this design experience will be applied to subsequent phases. The Design Manual, Drafting Room Manual, and Parts Selection Book reflect advances made in the state-of-the-art in engines of these types by the up-dating of these three manuals and other documents to which the information applies.

6. Documentation

Table 1 enumerates the standards publications that will be used as requirements, or as references during subsequent phases of the JTF17 engine program. The table also indicates the applicability of such publications to engine design, construction, and test.

D. PHASE II-C SUMMARY

P&WA's standardization program during Phase II-C of the SST program has contributed to the successful establishment of new standardized hardware in the current JTF17 engine program. It also provides substantiation for these parts for subsequent phases of the SST program. These standard hardware parts include flange seals, fasteners, and fluid fittings. Other indications of significant progress are the approximately 550 revisions and additions issued in the Design Manual, Drafting Room Manual, and Parts Selection Book since the start of Phase II-C.

The standardization program for Phase III will be a continuation of the program followed under previous phases, with particular emphasis placed on those efforts relating to improvement of standards already implemented for the JTF17 engine. This emphasis is normal during this phase of an engine development program, as feedback of information from the manufacturing and test activities becomes available to the originators of the standards. Close liaison will be maintained between the Standardization Quality Assuranc Maintainability, Value Engineering and Reliability Groups to assure maximum benefits to the program from standardization.

E. STANDARDIZATION EXPERIENCE

The need for effective standardization practices in the design, development, production, and maintenance of engines is well recognized. Standardization has always been an important continuing activity at Pratt & Whitney Aircraft. As early as 1938 P&WA participated in the writing of Aeronautical Material Specifications (AMS). That year marked the beginning of standardization efforts in this country's aircraft engine industry. Standardization at Pratt & Whitney Aircraft is a management-directed effort utilizing proved procedural and documentation techniques to achieve desired goals including cost reduction, reliability, maintainability and safety.

A Design Standards Department was formed at Pratt & Whitney Aircraft in 1940 to establish a common engineering language and to eliminate unnecessary repetitive design effort. Since then, this department has worked with the Government and the aerospace industry to establish acceptable standard hardware, materials, and specifications, as well as to promote their usage.

At present, the Design Standards Department is staffed by approximately 30 persons having a total of over 400 years of company experience. The department is composed primarily of graduate engineers with design, drafting, or industry standards experience. Other department personnel include specialists in such fields as specification writing, manufacturing techniques, and drafting procedures. The specialized talents of personnel in other areas of the Design Engineering Department augment the efforts of the Design Standards Department. For example, assistance is obtained in the establishment of (1) design criteria for spin testing, low cycle fatigue analysis, vibration analysis; and (2) hardware configurations for frequently used design elements such as splines, seals, fluid connectors, and bearings.

The metallurgical, manufacturing, quality assurance, reliability, purchasing, accounting, and product support areas also support the standardization effort. Each task receives the required engineering, scientific, and managerial surveillance.

Pratt & Whitney Aircraft first participated in joint Government-Industry standardization efforts when a committee was formed in 1941 to create standards for aircraft engine parts. Since then, P&WA has actively participated in all aerospace and Government-Industry standardization efforts. Current representation includes the following:

Aerospace Industries Association	(AIA)
American Standards Association	(ASA)
Society of Automotive Engineers	(SAE)
American Society for Testing Materials	(ASTM)
American Welding Society	(AWS)
American Society of Metals	(ASM)
Investment Casting Institute	(ICI)
Air Transport Association	(ATA)
Joint Industry-Military Standards Committee	(JIMS)
American, British, Canadian Conference on Unification of Engineering Standards	(ABC)
International Organization for Standards	(ISO)

Pratt & Whitney Aircraft has 618 different Aeronautical Material Specifications in its current parts lists (of a possible 1117 that have been released by the AMS Committee), and uses 234 MS and AN aircraft engine industry coordinated standards (of a possible 446) in 38,150 applications on its current engines.

Table 1. Pratt & Whitney Aircraft Standardization Documents

Commercial Engines

	Design	Construction	Test
		Phase	
Military			
Air Force-Navy Aeronautical (AN and AND) Standards	X		
Air Force-Navy Aeronautical (ANA) Bulletins	X	X	X
Handbook of Instructions for Aerospace Systems Design (HIASD)	X		X
Handbook of Instructions for Aircraft Designers (HIAD)	X		X
Military Specifications - Materials and Processes	X	X	X
Military Standard (MS) Parts	X	X	X
Military Standards (MIL STDS)	X	X	X
Federal			
Advisory Circulars (FAA)	X		X
Aircraft Designer's Handbook for Titanium and Titanium Alloys (FAA)	X	X	
Federal Aviation Regulation (FAA)	X		X
Federal Specifications - Materials and Processes	X		
National Bureau of Standards Handbooks (e.g., H-28)	X		
Qualified Products Lists (QPL)	X	X	
Tentative Airworthiness Standards for Supersonic Transports (FAA)	X		X
Industry			
Aerospace Information Reports (AIR)	X	X	X
Aerospace Material Specifications (AMS) - Materials and Processes	X	X	
Aerospace Recommended Practices (ARP)	X	X	X
Aerospace Standards (AS)	X	X	X
Air Transport Association (ATA) Standards	X	X	X
Aluminum Association (AA) Standards	X		
American Chemical Society (ACS) Standards	X		

Table 1. Pratt & Whitney Aircraft Standardization Documents (Continued)

Commercial Engines

	Phase: Design	Phase: Construction	Phase: Test
Industry (Continued)			
American Iron and Steel Institute (AISI) Standards	X		
American Society for Metals (ASM) Standards	X		
American Society of Mechanical Engineers (ASME) Standards	X	X	X
American Society for Testing Materials (ASTM) Standards			X
American Standards Association (ASA) Standards	X	X	X
American Welding Society (AWS) Standards	X	X	
National Aircraft Standards (NAS)	X		
Society of Automotive Engineers (SAE) Standards	X		
Pratt & Whitney Aircraft			
Airfoil Section Properties Manual	X	X	
Assembly Instruction Sheets		X	
Component Calibration Schedules			X
Design Manual	X		X
Design Reports	X		X
Dimensional Control Standards (DCS)		X	
Drafting Room Manual	X	X	X
Engineering Bulletins		X	X
Engineering Instructions		X	X
Etch Inspection Standards (EIS)		X	
Experimental Engineers Handbook		X	X
Fluorescent Penetrant Standards (FPS)		X	
Grain Size Standards (GSS)		X	
Magnetic Particle Standards (MPS)		X	

Table 1. Pratt & Whitney Aircraft Standardization Documents (Continued)

Commercial Engines

	Phase		
	Design	Construction	Test
Pratt & Whitney Aircraft (Continued)			
Materials Control Laboratory Manual		X	X
Materials Manual	X	X	
Packaging Manual	X		X
Parts Selection Book	X	X	X
Process Material Controls (PMC)		X	
Process Operation Procedures (POP)		X	
Production Engineering Instructions (PEI)		X	
Production Engineering Procedures (PEP)		X	
Production Engineering Specifications (PES)		X	
Purchase Specifications	X	X	
Quality Control Manual		X	
Quality Review Procedures	X	X	
Security Standard Practice Procedures Manual	X	X	X
Sonic Inspection Standards (SIS)		X	
Specifications - Design	X	X	
Specifications - Materials and Processes	X	X	
Specifications - Quality Assurance		X	
Standard Manufacturing Equipment Manual	X	X	
Standard Procedures Manual	X	X	X
Standard Tool Hardware Manual	X	X	
Surface Finish Standards (SFS)		X	
Surface Temper Standards (STS)		X	
Technical Data (TD) and Technical Data Memoranda (TDM)	X		X
Test Instruction Sheets			X
Tool and Gage Design Manual	X	X	
Utility and Packaging Parts Selection Book	X	X	X
Value Engineering Handbook	X		
Visual Inspection Standards (VIS)		X	
Welding and Brazing Manual	X	X	
X-Ray Standards (XRS)		X	

SECTION VI
PRODUCT SUPPORT PROGRAM

A. PRODUCT SUPPORT PROGRAM OBJECTIVES

The Pratt & Whitney Aircraft JTF17 Product Support Program for Phase III, the SST Prototype Construction and Flight Test Phase, is established to satisfy the following objectives:

1. Successful operation and support of the JTF17 engine during ground tests at AEDC, Tullahoma, and at the airframe manufacturer's test facility.
2. Field support of the 100-hour aircraft flight test program.
3. Timely and adequate engine training of FAA, airframe and airline personnel.
4. Preparation, publication and distribution of Technical Data and Handbooks required for operation, maintenance, overhaul and logistics support of the JTF17 engine.
5. Selection, provisioning, procurement, distribution and management of engine spare parts required for ground test, flight test and overhaul.
6. Design, procurement, validation, distribution and evaluation of engine tools and equipment (GSE).
7. Evaluation of the training, data and handbooks, spare parts usage, ground support and technical services experience during Phase III to ensure a successful transition to commercial airline operation.

B. SUMMARY

In order to ensure successful operation during the Prototype Construction and Flight Test (Phase III), Production Development and Certification (Phase IV) and Production and scheduled Airline Operation (Phase V), P&WA will follow the Product Support Plan described below.

The plan is based upon the experience gained in the support of numerous engine/airframe programs resulting in more than 39,000,000 hours commercial and 44,000,000 hours military turbojet operation. Specifically, the ground and flight test support requirements for the SST program parallel those of the J58 Mach 3-Plus program, including complete P&WA responsibility for planning, providing and managing the technical services, spares, GSE, training, technical publications, and engine maintenance and overhaul. Documentation establishing mutual understanding and agreement of P&WA and the airframe manufacturers' support responsibilities has been signed and will be implemented with the airframe manufacturer selected throughout the ground and flight test programs.

The basic elements of the plan are described in the following pages and consist of:

Contractor Technical Services

Technical Data and Handbooks

Ground Support Equipment

Spare Parts

Training and Training Equipment

All elements will be involved in the support of the JTF17 SST program during the following Phase III activities.

Airframe Manufacturer Plant Coordination

Engine Ground Test Operations at AEDC

Engine Ground Test Operations at Airframe Manufacturing Facility

Prototype Flight Test Program

The services and equipment utilized during Phase III will contain the provisions necessary for successful transition and follow-on in Phases IV and V.

Particular attention during the flight test phase will be focused on, but not limited to, the evaluation of:

- Installed and shop engine inspection techniques such as radioisotope, borescope and chip detectors
- Installed and shop engine maintenance and repair procedures
- Ground support equipment, engine shop and test stand facilities requirements
- Parameters and engine trend analysis in determining engine condition through the use of Airborne Integrated Data System
- Engine parts condition and consumption
- Engine operation, limits and troubleshooting procedures
- Technical data and handbooks.

Analysis of the above will be conducted by the JTF17 organization at FRDC, and changes in concept and procedures will be effected as necessary during Phases III and IV to provide successful support of commercial airline operation.

C. ORGANIZATION

The product support plan will be directed by the Manager, JTF17 Product Support who reports directly to the JTF17 Program Manager.

The Product Support organization will expand as the needs of the program expand, and, conversely, when certain elements are phased out, the organization will be reduced. The current Phase II-C Product Support group will form the nucleus of the Phase III organization. The staff of the Product Support organization will be selected from personnel experienced in working with commercial airline and high Mach number military programs. The organization that will implement the JTF17 engine product support plan is shown in figure 1.

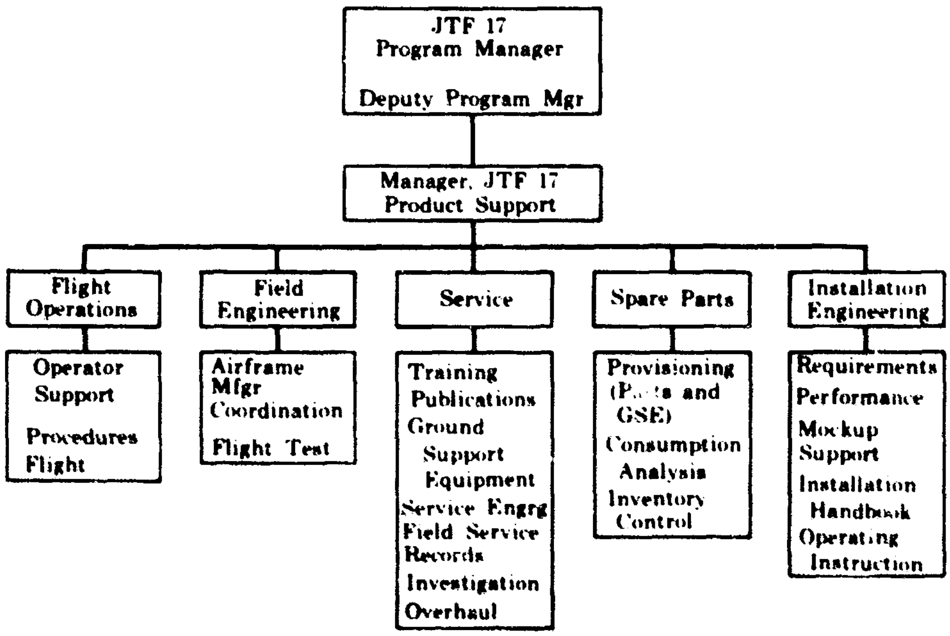


Figure 1. JTF17 Organization Chart for Product Support FD 17518 FVI

The Service group will be responsible for:

- Assuring that the contractor technical services are provided on time and on station as discussed in Paragraph D below
- Assuring that the manuals and handbooks described in Paragraph C below fulfill their intent and are delivered on time
- Assuring that the GSE for the ground and flight test programs and the operational phase is available and in place (see Paragraph Hi below)
- Assuring that the JTF17 Training Program as discussed in Paragraph J below meets its training objectives
- Assuring that the service records, overhauls, and materials investigation are completed as required for the JTF17 program.

The Spare Parts group will be responsible for provisioning parts and operating the logistics store for the ground and flight test programs.

The Installation Engineering group will be responsible for:

- Assuring the coordination of the installation design and performance requirements
- Assuring that support is provided in constructing and updating the engine mockups.

The Field Engineering group will be responsible for:

- The day-to-day direct contact with the airframe manufacturer
- Local engineering coverage during the ground test and flight test programs
- Engine mockup coordination
- Coordination of installation and performance requirements.

The Flight Operations Engineering group will be responsible for:

- Assuring that the airline flight crews are properly trained in JTF17 engine operating techniques
- Assuring that good engine management procedures are employed by flight crews in scheduled airline operation
- Recommending changes to procedures to resolve special operational problems.

Figures 2 and 3 present the schedule for activation of the various groups in the JTF17 Product Support Program at FRDC, and in the field.

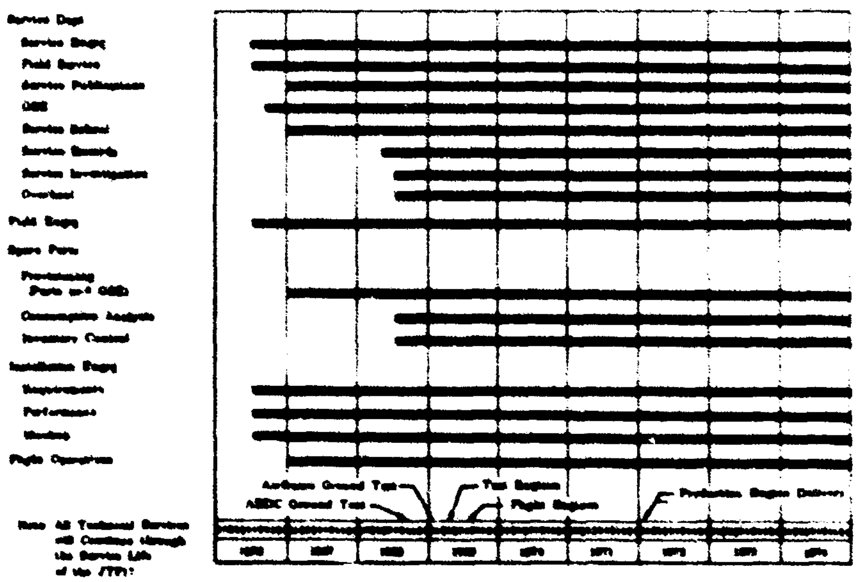


Figure 2. JTF17 Product Support Technical Services, FRDC — FD 17521 FVI

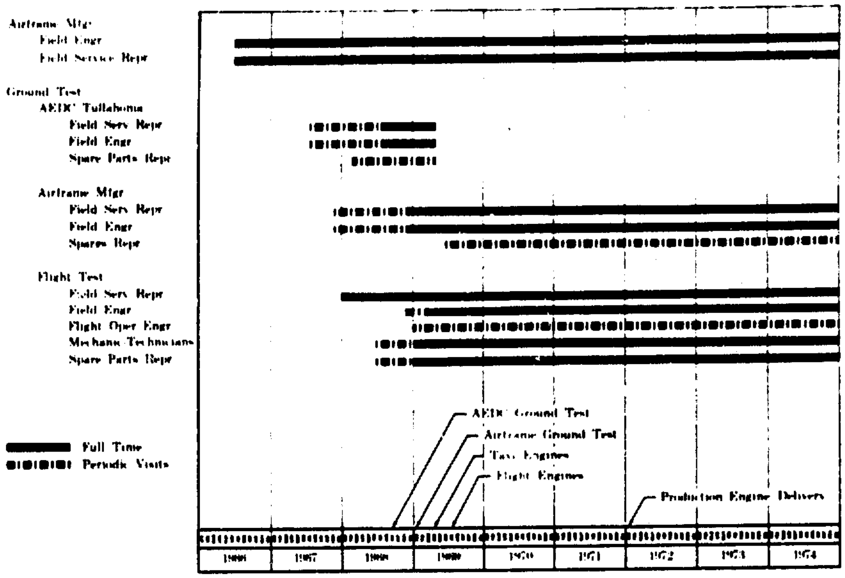


Figure 3. JTF17 Product Support Technical Services, Field

FD 17522
FVI

D. PRODUCT SUPPORT INTERFACE

Successful completion of the airframe-contractor-conducted Phase III ground and flight test programs will require the support of Pratt & Whitney Aircraft. Accordingly, Compatibility Agreements have been negotiated with the airframe contractor setting forth the understandings and responsibilities of the parties with respect to the support of these programs. The reader is referred for details to copies of the agreements which are included in the airframe contractor's proposal.

While the agreements set forth responsibilities, schedules and other commitments of each party, it will be necessary to coordinate detail plans with the airframe contractor during Phase III. The detail planning will be generally in accordance with this paragraph.

1. Technical Services

P&WA will provide qualified Field Engineers, Field Service Representatives, Flight Operations Engineers, Spare Parts Representatives and Mechanic-Technicians as appropriate at the various field activities.

A staff of Field Engineers, Service Engineers, Installation Engineers, Spare Parts personnel and other specialists at the Florida Research and Development Center will provide technical direction and backup to the field personnel.

2. Airframe Manufacturer Coordination

Experienced Field Engineers and Field Service Representatives, presently located at the Boeing and Lockheed plants will continue to provide direct liaison with the selected airframe manufacturer in preparation for and during the ground, flight test, and airline operation programs.

These personnel will continue to supply the manufacturer the required engine performance data, engine/airframe technical considerations, mockup coordination, product support, maintainability, reliability, and safety information. A more detailed description of the functions of these P&WA field personnel is presented in paragraph K of this section.

The Installation Engineering Group will continue to provide the in-house backup support for the field engineers.

This group will coordinate installation compatibility requirements and performance requirements. The Installation Handbook, which has been supplied to the airframe manufacturers, and the JTF17 Engine Operating Instructions, which will be provided early in Phase III, will be kept up-to-date by this group. The processing of Field Surveys as required by Configuration Management will be conducted by Installation Engineering.

This group has assisted in the construction of the full-scale engine mockups supplied to the airframe manufacturers and will, in Phase III, provide support during the fabrication of the exact full-scale replica of the JTF17 engine.

These activities will be amplified by this group as the installation requirements become defined, thereby helping to assure a more compatible airframe/engine installation.

3. Ground Test - AEDC and Airframe Facilities

The Phase III program requires the delivery of engines to AEDC, Tullahoma, and to the airframe manufacturer's test facility for ground test programs. Field Engineers and Field Service Representatives will be assigned to each activity to assist the Government and airframe engineering test and maintenance personnel in the operation, performance evaluation and maintenance of the engines. In addition, project engineers and experimental engineers will be assigned by the Development Manager to follow these test programs at the test sites.

a. Technical Services

These P&WA personnel will coordinate the test programs, spare parts provisioning, equipment, and facility requirements with appropriate Government and airframe test personnel commencing 12 months prior to delivery of the first engines. They will be located at the test sites one month before engine delivery and will remain throughout the programs on a full-time basis as dictated by test scheduling requirements. This plan for coverage, supplemented by visits to our test facilities at FRDC by Government and airframe ground test personnel prior to and during their test programs, will ensure orderly planning and successful ground test programs.

The P&WA teams assigned will be experienced in all aspects of turbojet engine field support. In addition, they will receive intensive JTF17 training and will return to the Florida Research and Development Center periodically during the assignment for refresher training.

b. Communications

A daily exchange of information will be maintained between the JTF17 SST program field personnel and the supporting organization at FRDC via telephone and telegram reports. Detailed correspondence and periodic reports will augment the daily reporting. This information interchange will ensure that a current detailed knowledge of the test status, progress and problems is available to JTF17 Program Management and Development Engineering, Maintainability, Reliability, Safety, and Human Engineering. The flow of field data throughout the home organization is shown in figure 4.

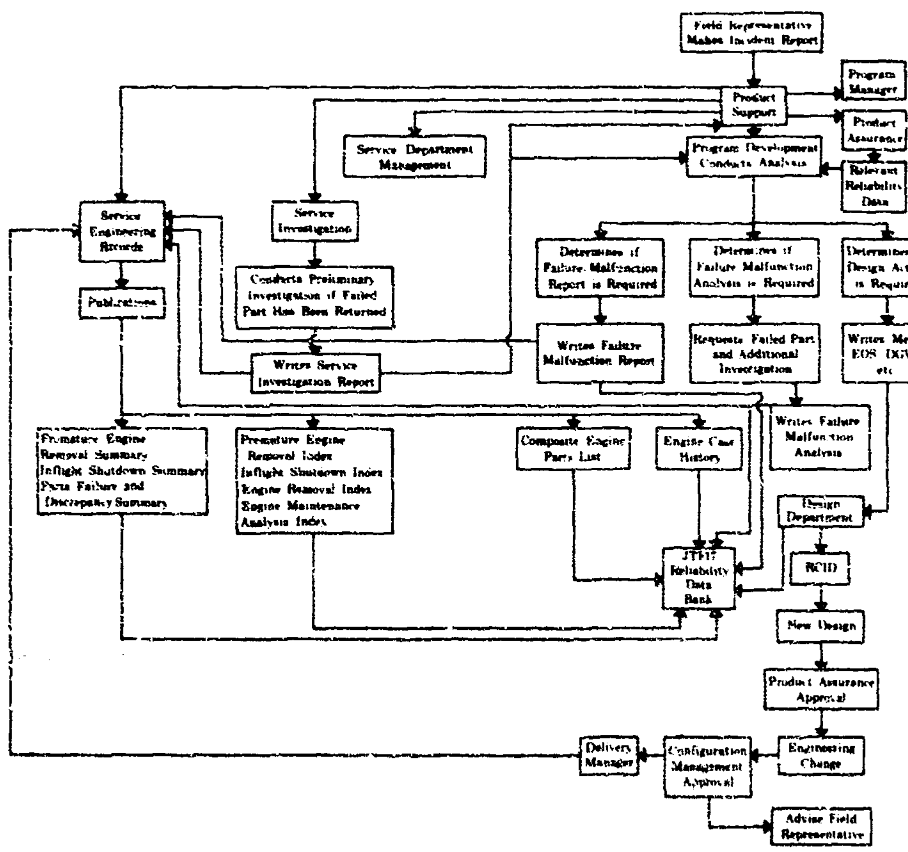


Figure 4. JTF17 Service Problem Information Flow Path FD 17520 FVI

Daily contact also provides the field personnel with current technical data and information required for the complete field support of the JTF17 engine.

c. On-the-Job Training for Non-P&WA Personnel

Field representatives will conduct continuing on-the-job training programs for Government and Airframe Manufacturer's personnel to supplement the P&WA Service School training discussed later in this plan, and also to provide advance information on Handbook revisions in the publication process. Experience has shown that this type of training is effective and necessary in ensuring that the customer test personnel are aware of the latest engine operating and maintenance procedures.

d. Spare Parts and Ground Support Equipment

Spare Parts and Ground Support Equipment required for engine test stand operation and maintenance will be delivered one month prior to receipt of the first engine at each test location. P&WA personnel will be responsible for maintaining accountability records and for issuing and reordering the required parts and equipment. They will also submit consumption data which will be collected and analyzed by Spare Parts and GSE personnel at FRDC for revisions to provisioning programing as necessary for continuing support during Phases III, IV, and V.

4. SST Flight Test

P&WA will provide complete engine support, except for line maintenance on the airplane as described below:

This support will include

- Light and heavy maintenance, modification, inspection, repair of the basic engine when not installed in the airplane.
- Engine test stand operation following maintenance action
- Assisting the airframe manufacturer, upon request, in installed engine line maintenance
- Spare parts and GSE
- Field Service, Field Engineering, Flight Operations, Spare Parts and Mechanic-Technician personnel
- Engine overhaul.

a. Maintenance Shop

An engine shop will be established at the flight test activity in a facility provided by the airframe manufacturer and will be completely staffed by P&WA personnel. Approximately 10,000 square feet will be required for shop, office, and storage space for spare parts and GSE. Layout and facility requirements such as electrical, pneumatic, and overhead hoist requirements will be established with the airframe manufacturer early in Phase III.

The shop will support the following functions:

- Engine receiving inspection
- Service Bulletin incorporation
- Engine repair and/or adjustment
- Engine heavy maintenance
- Maintenance of GSE

An engine test stand will be required for troubleshooting and for test and trim following engine maintenance. P&WA will coordinate instrumentation and facility requirements with the airframe manufacturer after Phase III go-ahead in accordance with the compatibility agreements.

b. Logistic Store

P&WA Spare Parts Representatives will establish a Logistics Store and will be responsible for the storage, accountability, issuance, reordering and reporting of spare parts and GSE consumption. Parts and GSE required for ground test, line maintenance and heavy maintenance will be used from this store.

c. Technical Services

A preliminary analysis has been made of the airframe contractor's flight test program, including accumulation of flight hours, number of engines and airplanes involved and maintenance tasks. As a result of this study supported by our current experience in similar support of the SR-71 airplane at Edwards Air Force Base, it is estimated that the personnel shown in table 1 will be required for flight line, engine shop, logistics store, and test stand support.

Field Service Representatives, Spare Parts Representatives and Lead Technicians will be assigned to the activity approximately three months prior to receipt of the first engine. Past experience indicates that this procedure is necessary for proper planning and establishment of the shop, storage and test facilities.

Field Engineers will make periodic visits to the test site commencing six months prior to receipt of the first engine and will be located there one month prior to receipt.

Flight Operations Engineers will make extended visits as required to support the flight test program.

All personnel will be experienced in turbojet engine field operation, maintenance, test and logistics support. They will receive intensive training on the JTF17 in their particular specialties at the Florida Research and Development Center. Upon completion of the ground test programs, personnel involved will be assigned to the flight test activity where feasible.

In addition to the foregoing, development engineers will be assigned by the JTF17 Development Manager to follow the flight test program and provide the necessary development engineering support at the flight test site.

Field personnel will maintain daily contact with the JTF17 project organization at FRDC in the same manner as described in the Ground Test section of this plan.

Table 1. Estimated Personnel Required for Flight Line, Engine Shop, and Test Stand Support

a. One Shift Operation

Personnel	Activity: Eng Shop	Test Stand	Flight Line	Office	Spares Stores	Tool Room	Total
Svc. Repr.	1	1	2	1			5
Spare Parts Repr.					1		1
Lead Technician	1	1					2
Technician	12	4					16
Inspector	2	1					3
Admin.				2	3	1	6
Field Engr.		1	1				2
Flight Ops. Engr.			1				1
							36

b. Two Shift Operation

Personnel	Activity: Eng Shop	Test Stand	Flight Line	Office	Spares Stores	Tool Room	Total
Svc. Repr.	2	2	4	2			10
Spare Parts Repr.					2		2
Lead Technician	2	2					4
Technician	20	8					28
Inspector	3	2					5
Admin.				3	4	1	8
Field Engr.		1	1				2
Flight Ops. Engr.			2				2
							61

d. Engine Overhaul Program

Flight Test Status engines delivered for Phase III flight test will have an initial TBO of 100 flight hours. As we accumulate flight experience, it is estimated that it will be increased to 300 hours by the time the FTS engines are replaced by Production engines during Phase IV.

As a result of our experience with the J58 in the Mach 3 YF-12 and SR-71 and many other programs, it is realized that engines will encounter Foreign Object Damage necessitating their premature removal and return to an overhaul facility. We estimate that the resulting effective TBO for the FTS engines will be 65 hours during Phase III and will increase to 210 hours in Phase IV.

As a precaution, our planning also anticipates that two of the four engines at the ground test activities may be returned for overhaul.

The overhaul schedule is contained in the Detailed Work Plan, Volume V, Report H.

JTF17 engine overhauls that may be required during the ground and flight test programs will be accomplished at the Florida Research and Development Center.

The overhaul processes of disassembly, inspection, repair, updating, assembly and test will be the responsibility of the Engine Delivery Group.

Technical direction, including extent of disassembly and repair, Engineering Changes incorporation, testing to be performed, etc., will be provided by the JTF17 Product Support Service Engineering group. This group will also be responsible for monitoring of engines in the overhaul process to avoid delays by anticipating and expediting parts requirements, and in conjunction with Development Engineering expediting resolution of technical problems that might arise.

The Overhaul Manual will be used by P&WA personnel during Phase III overhaul activity, thereby permitting a progressive validation of its various sections throughout Phases III and IV, to ensure a complete and detailed manual for airline operation. In like manner, overhaul tooling will be continually reviewed to ensure that the final designs meet airline overhaul equipment requirements.

By conducting overhauls at the FRDC facility, program personnel from Development Design and Product Assurance including Reliability, Maintainability, Human Engineering and Safety will be able to observe engine parts condition and overhaul practices and initiate corrective Engineering Change action and/or procedural changes where required.

Detailed reports of engine condition and spare parts usage for each overhaul will be distributed to Program Management and Development and Product Assurance Sections of the JTF17 organization.

E. POST SALES PRODUCT SUPPORT

Pratt & Whitney Aircraft's product support organization currently in existence will be used to support the JTF17 engine in airline operation. This organization is described in paragraph K of this plan.

Specific details of support in the elements of training and training equipment, technical data and handbooks, spare parts and ground support equipment are discussed in the following sections which also describe

Phase III product support activities. Although some airlines will establish their own facilities to overhaul the JTF17 during regular commercial service, P&WA will provide a continuing program at its overhaul and Repair Department at Southington, Connecticut, for those operators requesting it. In addition, P&WA will support certain types of repairs which might be less expensive if accomplished at a manufacturing facility. These services are currently being provided for other P&WA engine models.

F. AIRLINE INPUTS

Recommendations and constructive criticism have been received and will continue to be solicited from airline operators during the Phase III engine development program and the ground and flight test programs. Close liaison with the airlines will be maintained during Phase III and follow-on phases by:

- Visits by members of the JTF17 team to airline operators' main bases
- Visits by airline personnel to the Florida Research and Development Center both individually and as members of airline industry committees
- Observation of operation of P&WA JTF17 test stand and maintenance and overhaul shops by airline personnel
- Liaison by P&WA Service Representatives and Flight Operations Engineers currently stationed at or periodically contacting more than 200 operators throughout the world
- Formal program reports as appropriate.

During Phase III and later phases, the JTF17 will be included on the agenda of the annual meeting of airline personnel sponsored by the Product Support organization at East Hartford. These meetings, which have been conducted for the past 8 years, provide a unique opportunity for interchange of information and ideas between airline representatives and P&WA.

G. TECHNICAL DATA AND HANDBOOKS

Data and Handbooks required for operation, maintenance, repair, overhaul, test, and logistic support of the JTF17 engine will be published and distributed by the Service Publications Group in accordance with the following criteria.

1. Format

Engine Maintenance and Overhaul manuals, Illustrated Parts Catalogs, and Service Bulletins will be in strict compliance with ATA Specification No. 100.

Installation Handbooks, Operating Instructions, Special Tool Manuals and Facility Planning Manuals, which are not required by ATA Specification No. 100, will be presented in accordance with the then current standard P&WA format that will be used on other commercial airline engine programs.

2. Schedules

Pratt & Whitney Aircraft will provide publications to support the JTF17 engine in accordance with the schedules shown in figure 5. As shown, their distribution is keyed to engine deliveries and other milestones to ensure timely availability.

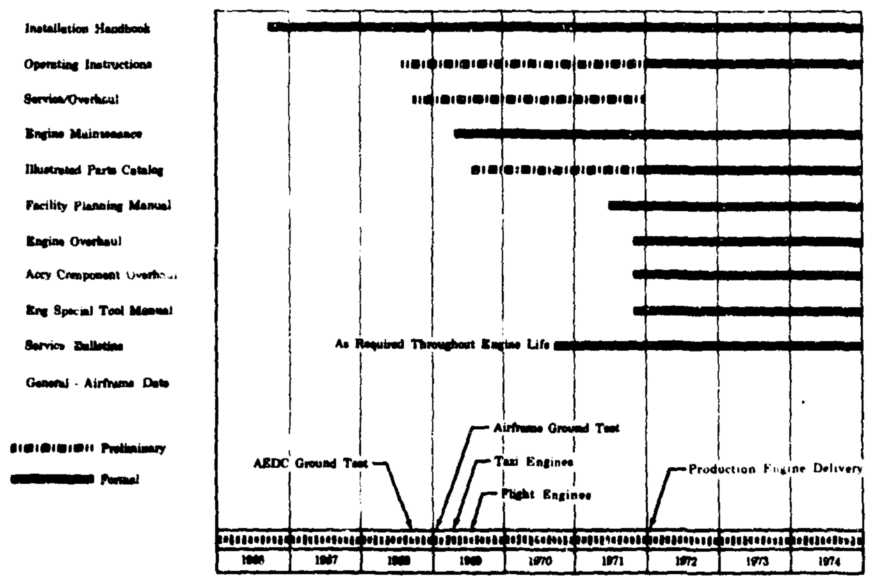


Figure 5. Technical Data and Delivery Schedule FD 16664 FVI

All publications will be updated every 90 days, or more frequently if required, to reflect changes in engine configuration, operation, test, maintenance, etc. The interval between the generation of product and service improvement data and the incorporation of these data in affected publications will be kept to an absolute minimum, governed only by publication production time subsequent to data cutoff.

3. Accuracy

The JTF17 publications will be prepared by a team of experienced technical writers. Each publication will be reviewed by Product Support technical specialists and by appropriate program Product Assurance personnel. All basic publications and revisions thereto will be validated prior to issuance.

4. Comprehension and Completeness

All data and handbooks will be written in a clear, precise manner with short and direct sentences and paragraphs. The scope and purpose of each publication will be stated in the introduction; detailed indexes as well as tables of contents will be included. Illustrations, charts, graphs, and tables will be employed to minimize the need for complex explanations, and abbreviations or complex technical terms will be fully explained. Cautions and warnings will be included in accordance with ATA Specification No. 100 requirements to eliminate the possibility of hazard to personnel or equipment.

The basic publications will contain all available data required for support of the JTF17 engine. For example, approximately 450 pages will be included in the first issue of the Maintenance Manual, approximately 600 pages in the Overhaul Manual, and approximately 300 pages in the Illustrated Parts Catalog. Frequent revisions will be issued as discussed above.

5. Publication Description

A brief description of the data and handbooks to be delivered is presented below.

a. Installation Handbook

The Installation Handbook provides information to assist airframe powerplant engineers and designers in planning the installation of the JTF17 in the SST aircraft. It contains detailed description, engine specifications, installation requirements and recommendations and operating test instructions. These data will be supplemented with schematics, drawings, and test curves to assure that engine as well as airframe requirements are met.

The first issue of this handbook was delivered to the airframe manufacturers on 8 August 1966.

b. Operating Instructions

Operating Instructions will be presented in the form of a general engine operating instruction supplemented by specific JTF17 engine operating instructions. This will provide the necessary operating information, procedures, operating curves and engine limits.

c. Service/Overhaul Manual

The Service/Overhaul Manual is not required by ATA Specification No. 100; therefore, it will be prepared to a standard P&WA format.

It will be a preliminary manual for Phase III, with maintenance data for ground test engines and overhaul data for ground and prototype flight test engines. The information contained in this manual will be developed into two formal manuals during Phase IV: the Maintenance Manual and the Overhaul Manual for the production engines.

d. Engine Maintenance Manual

The Engine Maintenance Manual covers all maintenance practices including servicing, disassembly and assembly, inspection and repair, and extensive troubleshooting procedures and includes an engine description.

e. Illustrated Parts Catalog

The Illustrated Parts Catalog lists and illustrates the assemblies and detail parts that comprise the JTF17 engine. It will encompass a

numerical parts list and a complete assembly parts list with indexes. It will also list accessory component vendor equipment, units per assembly and nonprocurable parts. Service bulletins that have been written and that affect the parts will be referenced in the Parts Catalog.

f. Engine and Vendor Component Service Bulletins

Each Engine and Vendor Component Service Bulletin will cover planning information, engine or component effectivity, reason for the bulletin, recommended compliance, manpower requirements, material cost and availability, and tooling information relating to parts repair or modification.

g. Engine Overhaul Manual

The Engine Overhaul Manual provides engine description and instructions for complete overhaul of the engine including teardown, inspection, repair procedures, cleaning, plating, balancing, test and reassembly.

h. Accessory Component Overhaul Manual

The Accessory Component Overhaul Manual covers the inspection and overhaul requirements of all JTF17 engine accessory components. Provisions are made for the incorporation of similar data prepared and distributed by affected vendor accessory component manufacturers.

i. Facility Planning Manual

The Facility Planning Manual aids the customer in planning the facilities required to maintain, overhaul, and test the JTF17 engine. It includes progress charts, suggested operation sheets, parts processing charts, assembly groups, solutions and materials, tools and equipment, and suggested facility layout and design.

j. Engine Special Tool Manual

The Engine Special Tool Manual contains a numerical listing of all P&WA tools to be used in the maintenance and overhaul of the JTF17 engine. It also describes the use and approximate price of each tool.

k. General - Airframe Data

Pratt & Whitney Aircraft will provide engine data to the airframe manufacturer for inclusion in his flight and maintenance manuals. P&WA will also review and comment on, in an expeditious manner, the airframe manufacturer's drafts containing JTF17 operating and maintenance data prior to publication in his manuals.

H. GROUND SUPPORT EQUIPMENT

Specialized equipment required for the maintenance, overhaul and test of the JTF17 will be designed, validated and released for manufacture by the Service Tools and Equipment Group.

1. GSE Concept

The modular design and other maintainability features of the JTF17 described in the Maintainability Plan, Section I of Report F, will permit extensive maintenance of the engine while installed in the airplane. In order to assure that the engine capability will be retained during the installation design process, P&WA has reviewed the basic engine maintenance concept with the airframe contractor maintenance and propulsion system design groups. During Phase III, close engine/airframe coordination will be maintained with the manufacturer to ensure that adequate engine tooling will be designed for all possible installed maintenance and inspection tasks and that the engine installation design does not unnecessarily limit the installed maintenance capability.

Engine shop maintenance and overhaul can be performed either in the horizontal or vertical positions, and tooling will be designed to be used with either method.

GSE and facilities utilized for other P&WA engine models will be reviewed in order to avoid duplication and, where possible, modified to permit common usage.

Experienced personnel from Program Maintainability, the Tools and Equipment Group, Design, Maintainability Group and Service Engineering have conducted an extensive study of the JTF17 engine and of current airline practices in establishing the GSE concept which will be utilized in SST operation.

2. Design

Ground Support Equipment designers and process planners will design all special engine equipment required for field support of the JTF17 in response to requirements established by the Product Support Manager with details supplied by Engine Design, Service Engineering, Maintainability, Human Engineering, and Safety.

Tooling and special test equipment provided for the Phase III ground and flight test programs will be of the same quality and design standards as employed for airline operation. The P&WA Tool Design Manual, which specifies standards, instructions, and procedures, will be adhered to.

By this procedure, valuable experience will be obtained prior to the release of designs for the production engine. Where experience in the flight test phase confirms the advantages of the GSE design and production engine configuration permits, the same tool will be released for production. It is anticipated that by this means, a majority of the production tools and test equipment will have been "field validated" by actual use in the flight test support program.

Ground Support Equipment design will be coordinated with the airframe contractor to avoid duplication of tooling for accomplishing installed maintenance.

3. **Equipment Validation**

Prior to release for service use, each new or modified tool will be validated by use on an engine. Personnel from the Tools and Equipment, Maintainability and Human Engineering will witness the verification of the maintenance tasks which will be performed by technicians with normal skill levels.

A Phase III GSE demonstration will be conducted for FAA, airframe contractor and airline personnel. Maintenance tasks involving Line Maintenance, Hot Section Inspection and Engine Heavy Maintenance will be performed during the engine maintenance demonstration as discussed in the Maintainability Plan, Report F, Section I. Equipment designed for the field will be used at this time and comments and recommended changes will be solicited from the attendees.

4. Delivery

Necessary engine equipment will be delivered to the ground and flight test activities one month prior to receipt of the first engine at the test location.

5. **Post-Sales GSE Support**

Planning for post-sales support of GSE will be accomplished in the latter stages of Phase III following the placement of firm orders for the SST by the airlines. As explained in earlier sections, it can be anticipated that a majority of the Phase III prototype designs will be suitable for use with the production engines. P&WA will sell the JTF17 GSE to the airlines or, if requested, will provide drawings and technical data to the airlines in order that they may manufacture the equipment in their shops or have it made by vendors of their choice. This practice has been followed in other P&WA commercial engine programs.

GSE support will be provided to operators on a continuing basis through the service life of the JTF17 engine.

6. **Change Control and Follow-Up**

Upon completion of validation, the further changes are accomplished under an Engineering Change system in the same manner as engine parts.

Each Engineering Change in process against the engine is reviewed by the Tools and Equipment Group to determine whether tooling is affected. If existing equipment must be replaced or modified, redesign is initiated and released by a Service Tool Engineering Change.

P&WA Field Service Representatives at ground and flight test activities will have as one of their responsibilities the reporting of success or difficulties encountered in routine use of the equipment by technicians at these locations. The reports will be reviewed by Product Support management and members of the Service Tools and Equipment group for corrective Engineering Change action where necessary.

Members of the group will make periodic visits to field activities prior to and during ground and flight test programs to assist in planning and witness use of the various equipment under field conditions.

7. Airline Overhaul Facility Surveys (Phase IV)

A survey of existing facilities will be initiated upon request of individual airlines to determine the most practical shop layout, to establish methods of modifying existing balancing equipment, component flow benches, engine test stands, etc., if such should be required to accommodate the JTF17.

The Service Tool and Equipment Group prepares a Facility Planning Manual and an Engine Special Tool Manual discussed under Technical Data and Handbooks, paragraph G of this section, to further assist the airlines.

I. SPARE PARTS

1. Description of Spares

Figure 6 is a sample page from the Design Engineering Numerical Parts List (Bill of Material) which has been condensed to reflect only the salable parts contained in the JTF17 engine. The sample is presented in part name (alphabetical) sequence and contains only one of a normal total of 225 pages. Although this figure is based on the current JTF17 Demonstrator Engine Bill of Material, it is considered to be representative of the prototype engine insofar as parts and assembly description (nomenclature) is concerned.

UNITED AIRCRAFT CORP. — PRATT & WHITNEY AIRCRAFT DIV., FLORIDA OPERATIONS

ENGINE PARTS LIST — ENGINEERING DEPT.

MODEL	DATE	SHEET NO	PART NAME
JTF17A-20	07/08/66		

PART OR ASSEMBLY NAME	CHANGE DESIGNATION	T S O		PART OR ASSY. NUMBER	UNITS PER ASSY.	ASSY'S PER ENGINE	TOTAL UNITS		ASSEMBLY NO.
BLADE-FAN ROTOR, 1 STAGE		C		2122401	44	1	44		2120012
BLADE-TURBINE ROTOR, 2 STAGE	C 10	C		2114502	88	1	88		2116082
CASE ASSY-INTERMEDIATE	F 5			2120038	1	1	1	B	2120000
DISK-COMPRESSOR, 4 STAGE, ASYO	A 1			2122214	1	1	1		2120013
DISK-TURBINE, 1 STAGE	B 3			2121901	1	1	1		2120015
DUCT HEATER ASSY				2119999	1	1	1	D	2120000
ELBOW-MAIN FUEL NOZZLE	1			2115465	1	10	10		2118023
FUEL CONTROL-MAIN, CJ-Q1	A 22			2116127	1	1	1	E	2120000
GEARBOX ASSY-MAIN	E 4			2119686	1	1	1	E	2120000
HOUSING-NO. 1 BRG, ASYO	A 4			2119636	1	1	1	B	2120000
HUB-FAN, ASYO				2116255	1	1	1		2116272
LINER-DUCT HEATER, CC, FRONT, ASYO				2127968	60	1	60		2119999
MANIFOLD-FUEL SUPPLY MAIN, ASYO	1			2117670	1	1	1	F	2120000
NOZZLE+SUPPORT-ASSY-FUEL, DTH, ZONE 1	B 2			2115986	10	1	10		2119999
PUMP-FUEL 2 STG MAIN				2118386	1	1	1	E	2120000
ROTOR+STATOR ASSY FAN	D 9			2120012	1	1	1	B	2120000
SHAFT-FAN DRIVE, TURBINE, ASYO	1			2116394	1	1	1		2120014
TANK LUBE OIL, ASYO	13			2109080	1	1	1	E	2120000
VANE-TURBINE STATOR, 1 STAGE, ASYO	F 1		AD	2114351		1		K	2120000

S=NOT RECOMMENDED FOR SPARES T=OPTIONAL PART NUMBER O=OVERSIZED AVAILABLE AN=ARMY NAVY PART NUMBER

Figure 6. Engine Parts List

Spare o be provided for support of the ground and flight test programs will fall into two categories.

a. Maintenance

Maintenance includes those parts which in the judgment of experienced Product Support Program personnel will be required for replacement and/or repair of installed parts or assemblies in the field. Support to be provided for field requirements will consist of those items which may be removed and replaced, together with those subassemblies and details required for engine and major assembly repair without the need for highly specialized machine tools and shop equipment.

b. Overhaul

Support to be provided for overhaul and repair requirements will consist of a full range of salable parts in varying quantities to cover complete disassembly, inspection, repair, assembly and test of JTF17 engines and of assemblies and subassemblies thereof.

2. Selection of Spares

Utilizing the JTF17 Design Bill of Material, Product Support Spare Parts Program Monitors and Technical Personnel will analyze and assign estimated maintenance and overhaul usage factors (expressed as a percentage) to each salable item. Selection of spare parts will be based on the judgment and experience of well-qualified personnel having a broad background of knowledge in the areas of maintenance and overhaul of P&WA engines in current commercial operation and in total support of the J58 Mach 3 engine. Reliability and maintainability data gained during development testing of the JTF17 will be utilized in establishing quantitative spares requirements. All parts selected as spares will be incorporated into a computer oriented Data File which will be continuously updated to reflect the effects of Engineering Change activity.

3. Procurement/Fabrication of Spares

Approximately 60 days prior to release for manufacture of the prototype JTF17 engines, a spares support list will be prepared by data extraction methods from the computer storage file. In the extraction process a computation of quantitative requirements for JTF17 maintenance and overhaul support will be made and the resulting list will be identified as a Recommended Spare Parts List. This list will be approved by the Product Support Manager and submitted as shown in figure 7, for review and coordination with airframe contractor personnel. Upon completion of this review and in accordance with applicable contractual agreements, the recommended Spare Parts List will be released for procurement or fabrication and delivery at a rate commensurate with delivery of the prototype engines. Procurement or fabrication, inspection and shipment of all spares will be the basic responsibility of the Delivery Material Control Department together with all ancillary departments. The Delivery Material Control Department will be responsive to the Product Support Manager in all matters affecting configuration, quantity and delivery of spares.

JOB 14002-01   0-20   12-06-65   PAGE 25

ITEM	PART NO	NOMENCLATURE	UPE	FM	OH	FM-QTY	OH-QTY	TOT-QTY	PRICE	TOT AMT	S-C
433	2038278	SEAT	48		10		480	480	4.74	2,275.20	1
434	2038281	LOCK	48		20		960	960	3.26	3,129.60	1
435	2038506	SUPPORT	1		5		5	5	82.20	411.00	1
436	2038536	GASKET	1	25	110		110	110	4.37	480.70	1
437	2038550	SPACER	1	10	25		25	25	2.12	53.00	1
438	2038584	BOLT	1	10	20		20	20	1.64	32.80	1
439	2038585	BOLT	1	10	20		20	20	2.55	51.00	1
440	2038681	PIN	2	5	50		100	100	1.78	178.00	1
441	2038751	SPACER	1	5	20		20	20	13.12	262.40	1
442	2038752	BRACKET ASY	1	5	10		10	10	27.12	271.20	1
443	2038815	GASKET	4	210	210		840	840	1.94	1,629.60	1
444	2038816	GASKET	1	50	100		100	100	2.58	258.00	1
445	2039258	BRACKET	1	5	10		10	10	119.96	1,199.60	1
446	2039259	SUPPORT	1	2	5		5	5	150.39	751.95	1
447	2039260	TIEROD	1	5	10		10	10	26.15	261.50	1
448	2039261	ROD END	2	5	10		20	20	32.21	644.20	1
449	2039262	SUPPORT	1	2	5		5	5	83.81	419.05	1
450	2039265	TIEROD	1	5	10		10	10	56.71	567.10	1

Figure 7. Recommended Spare Parts List

4. Handling and Repair

A P&WA facility will be established at the flight test site for the purpose of receiving, warehousing and issuing maintenance spares and to handle the return of repairable items to the Florida Overhaul Facility and/or to Vendor Overhaul facilities. Product Support Spare Parts Representatives will be assigned to man this activity and the Maintenance Spares Inventory will be reviewed and analyzed daily to assure that it will adequately support the Flight and Ground Test Programs at the maintenance level. Similarly, the Florida overhaul and vendor overhaul facilities will include segregated areas to receive, warehouse and issue all parts required for support of overhaul and repair jobs performed during the prototype program. Figure 8 depicts the anticipated flow of material during the course of the prototype program. The overhaul inventory will also be reviewed daily to assure that its content is adequate to support O&R requirements.

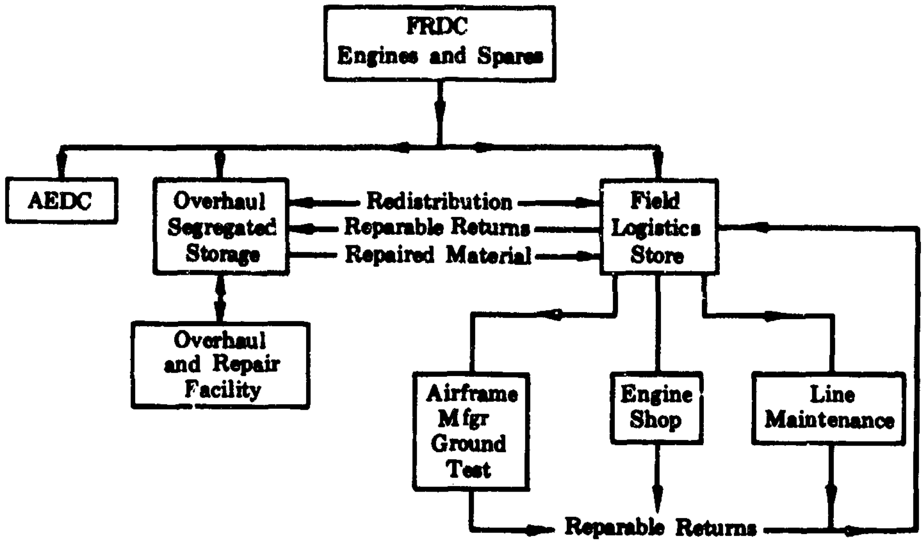


Figure 8. Anticipated Flow of Material During Prototype Program

FD 17519
FVI

5. Spares Support Summary

In addition to the provisioning of spares support in the manner described in the preceding paragraphs, a computer oriented data collection and storage system will be implemented which will reflect all pertinent history relating to the ordering, shipment, usage and inventory balances and values on all parts procured, delivered or on order for support of the prototype program. The format for the printed product of this system is shown in figure 9. Coincident with this information, a Computer Oriented Spare Parts Application Data List will also be compiled and maintained, which will reflect the engineering history and progression of all spare parts applicable to the JTF17 engine. A sample of the SPADL is presented in figure 10.

JOB NO. 14612 FLORIDA MASTER LIST EFF. 04-30-66 PAGE 231

PART NUMBER	NOMENCLATURE		UNIT PRICE		ORDERED QUANTITY	SHIPPED QUANTITY	FIRST SHIP.	LAST SHIP.	USAGE	LAST USE	BALANCE	PCT SC
2037115	SEAL			U/R	89	56	10-62	03-66	45	07-65	11	51
2037118	SHIELD			C/R	34	28	05-62	10-65			28	
				PSC	13	13	10-64	10-65			13	
2037122	GASKET	K		U/R	585	536	05-62	08-65	372	07-65	158	64
				PSU	98	98	03-63	08-65	5	10-65	93	
2037123	GASKET	K		U/R	405	377	05-62	09-65	259	07-65	118	64
				PSU	330	333	02-62	09-65	123	03-66	207	37
2037124	GASKET	K		U/R	496	466	05-62	10-65	291	07-65	177	59
				PSU	718	718	09-62	10-65	57	03-66	661	
2037125	GASKET			U/R	483	426	05-62	03-66	318	07-65	62	66
				PSU	377	352	02-62	04-65	187	04-66	165	50
2037126	GASKET	K		U/R	444	416	05-62	10-65	247	07-65	169	56
				PSU	205	205	11-62	12-65	69	04-66	136	34
2037127	GASKET	K		U/R	763	536	04-62	03-66	378	07-65	109	46
				PSO	602	470	02-62	03-66	222	03-66	248	
2037128	GASKET	K		U/R	446	405	05-62	02-66	214	07-65	191	46
				PSO	81	66	10-62	02-66	19	03-66	47	
2037129	GASKET	K		U/R	333	305	05-62	09-65	146	07-65	169	59
				PSU	78	76	10-62	07-65	19	03-66	59	
2037131	GASKET	K		U/R	393	265	05-62	02-66	195	07-65	170	50
				PSC	155	155	09-64	03-66	21	03-66	117	
2037225				U/R	3	3	05-62	09-64			3	
2037244				U/R	1	1	03-62	09-64	1			100
2037251				U/R	1	1	03-62	09-64			1	
2037266				U/R	1	1	02-62	09-64			2	
2037305				U/R	5	5	03-62	09-64	2		3	40
2037324	IL BEARING			U/R	80	59	02-62	11-65	59	06-65		74
2037364	IL SEAL			PSO	42	42	02-62	11-64	15	03-66	27	36
2037367	IL SEAL			U/R	45	45	10-62	12-64	45	05-65		100
				PSC	43	43	08-62	02-64	26	03-66	17	65
20374[illegible]				U/R			-	-			92	
2037478				U/R			-	-			1	
2037546	GASKET			U/R	143	103	11-62	12-64	67	07-65	116	35
				PSO	48	48	01-63	09-64			48	
2037691				U/R	414	414	02-62	09-65	101	07-65	313	
2037810	BEARING			PSU	86	86	02-62	09-65	109	04-66	23-	147
2037855	VANE			U/R	1	1	12-65	01-66			1	
2037873	RING			U/R	150	125	02-62	05-65	13		112	
2037884	PLATE			U/R	1200	800	04-62	02-66	175	07-65	85	62
				PSC	34	34	04-62	11-62			34	
2038006				U/R			-	-			1	
2038008	ASY BAND			U/R	22	22	07-62	12-65	9	07-65	13	41
				PSC	6	6	08-62	12-65	4	02-65	2	67
2038043	ROD END			U/R	35	31	01-62	06-65	16	05-65	21	
				PSU	20	20	09-62	06-65	1	02-65	19	
2038018	ASY TIE ROD			U/R	10	9	02-62	05-65	3	07-65	6	30
				PSC	11	11	06-62	09-65	1	02-65	10	
2038023	ASY BAND			U/R	24	16	07-62	02-66	8	07-65	10	
				PSU	4	4	08-62	06-63	5	02-65	1-	125
2038025	BRACKET			U/R	30	26	01-62	05-65	5	07-65	21	
				PSC	10	10	02-62	05-65			10	
2038026	LINK			U/R	173	158	02-62	09-65	52	07-65	106	30

Figure 9. Computer Summary of Data on Parts Procured, Delivered, or on Order for Support of Prototype System

PAGE 1

JT110-20 SPARE PARTS RECUPERATION DATA

JOB INDEX PART NUMBER | NOMENCLATURE | MAY BE RECUPERATED FROM | MAY BE RECUPERATED TO | ENGR CHANGE NO

FIRESEAL ASY
BOLT
BOLT
HOUSING ASY
MANIFOLD ASY
MANIFOLD ASY
RING ASY
INJ PROBE ASY
TURB ROTOR ASY
WASHER
HOUSING
BOLT
BOLT
BRACKET ASY
PUMP ASY
CABLE
BRACKET
BRACKET
MANIFLD ASY

JT110-20 SPARE PARTS APPLICATION DATA LIST - PROC

PAGE NO. 94

JOB NO.14018 PART NUMBER	NOMENCLATURE AND TRAILER DATA	UPE	FM PERCENT	OH PERCENT	PROCUR CURR	HIST	FACT	SCRP CAT	EC LT	INT CHG	EC INC	ENG APPLICATION	ITEM NO
	S/B 2081963 EC157292									N	1	1UP	
2071582	BOLT ADDED EC172100	2	15	30	099			A5	5	Y	2	49UP	2044
2071615	NUT CANC EC158998-3	40		25	000	-	PS		5	N	1	1UP	1473
2071616	TIEROD CANC EC158998-3	40		20	000	-	PS		5	N	1	1UP	1474
2071623	SPACER ASY S/B 2092909 EC158598	1		10	000	-	PS	R25	9	N	1	6UP	1475
2071634	BRACKET R/B 2096747 EC159243	1	10	25	001			A5		Y	2	10UP	1476
2071636	RETAINER R/B 2096748 EC159243	1	10	25	001			A5	7	Y	2	10UP	1477
2071641	TUBE ASY S/B 2101163 EC159954	1	5	10	000	-		R25		N	1	6UP	1478
2071642	SPACER HALF CANC EC159954	4		10	000	-	PS	R25	5	N	1	6UP	1479
2071643	SHIELD SEGMENT CANC EC159954	3	10	110	000	-	PS	R25		N	1	6UP	1480
2071648	BRACKET	1	10	25	100				5				1481
2071649	SLEEVE SEGMENT CANC EC157680B	2		10	000	-				N	1	44UP	1482
2071660	NUT SEE 2092323				000	-							2512
2071667	HOUSING ASY S/B 2095309 EC158938	1	10	5	000	-	PS			N	1	1UP	1483
2071669	GEARSHAFT S/B 2094957 EC158938	1	2	10	000	-	PS			N	1	1UP	1484
2071681	CLAMP	12	20	50	100				5				1485
2071682	CLAMP ADDED EC172100 ADDED EC172C58K	31	20	50	100			A5 R2	5	Y N	2 1	49UP 49UP	1486
2071683	CLAMP	25	20	50	100				5				1487
2071684	CLAMP	1	20	50	100				5				2594

Figure 10. Spare Parts Application Data List

6. Post Sales Spares Support

A plan for post sales spares support will be prepared in the latter stages of Phase III following the placement of firm orders for the SST by the airlines. Spares support will be accomplished generally in accordance with the following.

Approximately 12 months prior to the scheduled delivery of the first certificated production engine, or at a time mutually agreed to by the airlines, P&WA Product Support Spare Parts and Publications personnel will start the preparation of an Illustrated Parts Breakdown and a Parts Provisioning Breakdown. Upon completion and printing these publications will be submitted to all particpating airlines and a conference or conferences will be scheduled as required for the purpose of reviewing and selecting the parts to be initially procured.

After completion of the parts review conference and upon receipt of airlines orders, fabrication and delivery of parts will be accomplished in accordance with the P&WA Spare Parts Order lead time policy which is quoted as follows for engines in substantial volume production:

> "Pratt & Whitney Aircraft will plan its manufacture of JTF17 Spare Parts toward the objectives of delivering (1) items for which demand is relatively stable and predictable, within thirty days after receipt of order; (2) high value, low usage items during the period that the JTF17 engine is being manufactured in reasonable production quantities on a lead time basis shorter than thirty days when required to ensure that continuity of overhauls and availability of usable engines will not be disrupted; (3) all other items in 90 days and; (4) initial stockage orders within six months from receipt of order."

P&WA will conduct its initial and continuing post sales spare parts business in accordance with ATA Specification No. 100 and 300, and it will comply with the ATA Specification No. 200 to the extent that participating airlines desire P&WA performance under this specification.

J. TRAINING AND TRAINING EQUIPMENT PLAN

The Pratt & Whitney Aircraft Service School has been conducting customer training courses with a professional instructor staff since its founding in 1935. Turbojet engine training for approximately 18,000 engineers and technicians has been provided by the staff now numbering 25. A portion of this training has covered supersonic engines, including extensive courses on the J58 Mach 3 engine.

The necessity for proper and timely training of customer personnel to ensure the level of knowledge and capability necessary for engine operation, maintenance and logistic support is fully recognized, and courses covering all support phases of the JTF17 will be presented at the P&WA Service School.

A review of the engine design indicates that no special skill levels beyond those of maintenance personnel currently employed by airlines will be required for maintenance and operation of the JTF17.

The various types and content of training programs and starting dates are based upon our past experience and evaluation of the JTF17 and the schedules for SST ground, flight test and airline operation. Final schedules will be coordinated with the airframe contractor, FAA and airlines as Phase III progresses. In the case of the airframe contractor, reciprocal training will be coordinated to ensure the compatibility of both contractors training programs. All courses will be updated as required to reflect changes in engine configuration and operation and will be repeated as necessary to satisfy customer requirements throughout the service life of the engine.

In accordance with standard P&WA policy, there will be no direct fees to FAA, airline or airframe personnel for the training outlined in this plan.

1. Course Content

Each course has been designed to provide the content to meet the requirements of the students in attendance. Thus several different courses will be required to provide adequate training coverage with individual subjects receiving varying emphasis as indicated below.

Table 2 summarizes the types of courses, recommended customer personnel student categories and starting dates of the instruction.

The general training subjects, percentage of assigned times for the subjects and the duration of the courses are shown in table 3.

2. Staff Orientation

A three-day indoctrination program on the JTF17 engine configuration to provide key FAA, airframe and airline personnel with a general knowledge of the engine, its components, design, performance and logistics support.

3. Engine Ground Operation and Test

A one-week course to give FAA, airframe and airline personnel an understanding of the engine, its ground operation, testing requirements, instrumentation and procedures.

4. Engine Operation and Performance

A one-week program to provide powerplant engineering, operations and flight personnel with an overall picture of the engine, its component performance and its overall operation and performance characteristics.

Table 2. Types of Courses, Recommended Customer Personnel Student Categories and Starting Dates

	Staff Orientation	Operation and Performance	Expanded Operation and Performance	Operation and Test	Organizational Maintenance	Heavy Mainte-nance	Over-haul
	May 1967	July 1967	Phase IV	June 1968	July 1968	July 1973	July 1973
Airframe Contractor							
Key Supervision	x	-	-	x	-	-	-
Engineering	x	-	-	x	-	-	-
Inspection	-	-	-	x	-	-	-
Service	-	x	-	x	x	-	-
Training	-	x	-	x	x	-	-
FAA							
Key Supervision	x	-	-	x	-	-	-
Engineering	x	x	x	x	-	-	-
Inspection	-	x	-	x	-	x	x
Airline							
Key Supervision	x	-	-	-	-	-	-
Powerplant Eng.	x	x	x	-	-	-	-
Training	-	x	x	-	-	x	x
Inspection and Test	-	x	-	-	-	x	x
Maintenance	-	-	-	-	-	x	-
Overhaul	-	-	-	-	-	-	x
Flight Operation	-	x	x	-	-	-	-

Table 3. Percentage Assigned Course Time

Training Subject	Staff Orientation	Operation and Performance	Expanded Operation and Performance	Operation and Test	Organizational Maintenance	Engine Heavy Maintenance	Overhaul
Orientation, %	5	5	5	5	2	1	1
Engine Description, %	34	20	20	25	25	20	20
Functional Operating Principles, %	--	--	--	--	5	5	2
Component Performance, %	15	20	20	15	7	5	3
Accessories, %	15	10	10	15	15	12	12
Operation and/or Test, %	15	30	30	30	10	10	10
Performance Characteristics, %	8	15	15	10	3	2	2
Maintenance, %	8	--	--	--	33	45	--
Overhaul Process, %	--	--	--	--	--	--	50
TOTAL, %	100	100	100	100	100	100	100
Estimated Course Length, hr	24	40	80	40	80	160	160

5. Expanded Operation and Performance

An expanded two-week program specifically designed to assist airline flight operations and instructor personnel and FAA performance specialists will be presented prior to airline operation and will be scheduled as mutually agreed between the customers and P&WA.

6. Organizational (Line) Maintenance

A two-week program of engine familiarization, installed inspections and maintenance tasks will be provided for the airframe contractor to properly prepare his instructor and service personnel to carry out organizational type maintenance.

7. Engine Heavy Maintenance

An intensive four-week training program will be conducted on the engine, its components, inspection and maintenance techniques, heavy maintenance and repair procedures, ground operation and malfunction analysis. It is primarily established for lead airline technician and instructors and FAA inspection personnel. An operable engine will be utilized by the Service School for this program, and students will perform the various inspection and maintenance tasks, including extensive disassembly and reassembly of the engine. The engine will be run on a test stand following completion of assembly by the students. Engine tooling and GSE utilized during the course will be the same as that designed for airline maintenance.

The heavy maintenance courses will not be conducted during Phase III for airline or FAA personnel since P&WA personnel will perform all heavy maintenance support during Phases III and IV and will receive on-the-job training on the JTF17 at the Florida Research and Development Center.

8. Engine Overhaul

Overhauls required during the ground and flight test programs will be performed at FRDC by P&WA personnel. Customer overhaul training, therefore, will not be required until mid-1973.

The course will utilize an operational engine and will consist of complete disassembly, inspection, repair, assembly and test stand operation. Specialized courses in specific overhaul processes such as balancing, plating, repair procedures, etc., will be made available as desired by individual airlines and FAA personnel.

9. Engine Flight Simulator Training

Pratt & Whitney Aircraft will assist the airframe manufacturer by providing engine data necessary for the development of an SST simulator for flight crew training. Specific requirements and schedules will be coordinated to satisfy the training requirements.

10. Training Equipment

The Service School will employ modern training equipment and training aids; the types to be used will vary as dictated by the requirements of the different courses and are shown in table 4.

The following are brief descriptions of the equipment that will be used:

1. Training Texts - A Service School text prepared to provide important training information relative to the engine, its components, functional operation and performance. This will be supplemented by use of Maintenance, Overhaul, and other applicable manuals outlined in paragraph G.

2. Operable JTF17 Engine - Our experience has shown that detailed heavy maintenance and overhaul training can be completely covered only if the classroom instruction is supplemented by students actually performing maintenance and overhaul tasks. A prototype engine from the flight test program will be overhauled and updated for use in the training.

3. Engine Test Stand - The students will operate and test the engine on a production stand at East Hartford following completion of assembly during the heavy maintenance and overhaul courses.

4. Engine Tools and Fixtures - Ground Support Equipment designed for field use will be employed by the students as applicable during the Service School training.

5. Engine Parts and Cutaways - Engine hardware and cutaways will be used wherever possible during classroom training.

6. Schematic Diagrams - Student pass-out instruction sheets including various components and system schematics and layouts for use in analyzing operation including flow, pressure, and temperature parameters.

7. Vu-Graph Transparencies - A set of transparencies for classroom projection will be developed for each of the various courses.

8. Movies and/or Video Tapes - Will be used during the various courses as appropriate.

9. Miscellaneous - Notebooks, color pencil sets, thrust slide rules, etc., will be provided to the students.

Table 4. Training Aid Employment by Courses

Type Training Aid	Staff Orientation	Operation and Performance	Expanded Operation and Performance	Operation and Test	Organizational (Line) Maintenance	Engine Heavy Maintenance	Overhaul
Training Texts	X	X	X	X	X	X	X
Schematic Diagrams	X	X	X	X	X	X	X
Vu-Graph Trans-parencies	X	X	X	X	X	X	X
Motion Pictures and/or Video Tapes	X	X	X	X	X	X	X
Engine Parts and Cutaways	X	X	X	X	X	X	X
Operable Engine						X	X
Engine Test Stand						X	X
Engine Tools and Fixtures				X	X	X	X
Miscellaneous	X	X	X	X	X	X	X

K. EAST HARTFORD ORGANIZATION

1. Introduction

The concept of product support has been practiced by Pratt & Whitney Aircraft since it was founded 40 years ago. The first engines delivered were serviced in the field by the same people who built them in the factory. Gradually, a world-wide organization composed of specialist groups evolved to provide the many services necessary to assist the customers in all phases of commercial, military, and private aircraft engine operation, service, maintenance, overhaul and repair.

The product support operation at Pratt & Whitney Aircraft serves two basic functions:

1. To assist our customers by making available to them, through direct contact at locations throughout the world, the experience and capability of the entire division whenever assistance is required.

2. To provide our organization with a first-hand knowledge of our customers operational and maintenance experience in order that effective and efficient support may be provided when required.

Experience has shown that the second function is as important as the first, since the development of reliable and economical aircraft engines demands a practical understanding of the aircraft operators requirements. The best method of acquiring this understanding is through direct personal contact in the field.

The Product Support Department's involvement is a continuing process. It starts in the planning phase and continues during the design and development of the engine. Later it expands to direct support of the customer through ground test, flight test and delivery and extends throughout the service life of the engine.

2. Product Support Functions of Marketing Department

The product support groups of the marketing organization are primarily concerned with the early study, design and development and installation phases of the airframe-engine combination. These groups are oriented principally toward the airframe manufacturer in his role as either the initial customer or the associate contractor.

These sections of Marketing are shown organizationally in figure 11, followed by a brief description of their specific functions.

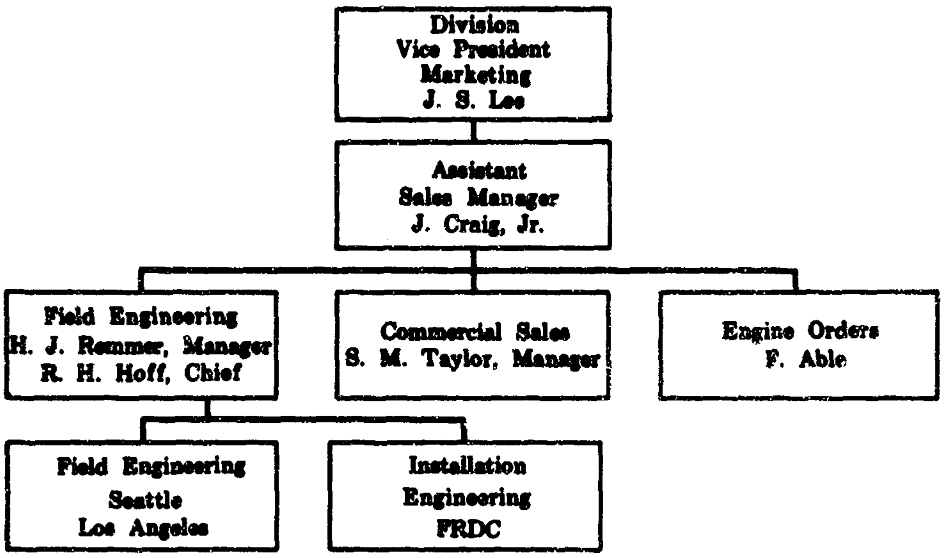


Figure 11. Product Support Functions of Marketing FD 17513
FVI

3. Field Engineering

The propulsion engineering requirements of the airframe manufacturer are coordinated through the local Field Engineering Group. Experienced engineers are assigned directly to the airframe manufacturer to provide assistance through the various stages of aircraft engine development, production, and installation.

During the initial study and preliminary design phases, the Field Engineer not only supplies the airframe manufacturer with engine performance and technical information including engine/airframe compatibility considerations, but assists the manufacturer in the proper use of this information. Mockup coordination to ensure the proper mating of engine and airframe installation interfaces is another function of the Field Engineer.

Pratt & Whitney Aircraft traditionally has continued an active engine development program long after certification and delivery. The Field Engineer, in this post-certification activity, ensures that engineering changes affecting the engine-aircraft relationship are properly coordinated with the airframe manufacturer.

Key field engineers have over 20 years company experience, and the average service of the entire group is over 14 years.

4. Installation Engineering

This department, consisting of more than 120 engineers, provides engine installation, performance and operation liaison for airframe manufacturers and operators through the Field Engineers.

A functional organization chart (figure 12) of the department and a description of its operation is presented on the next page.

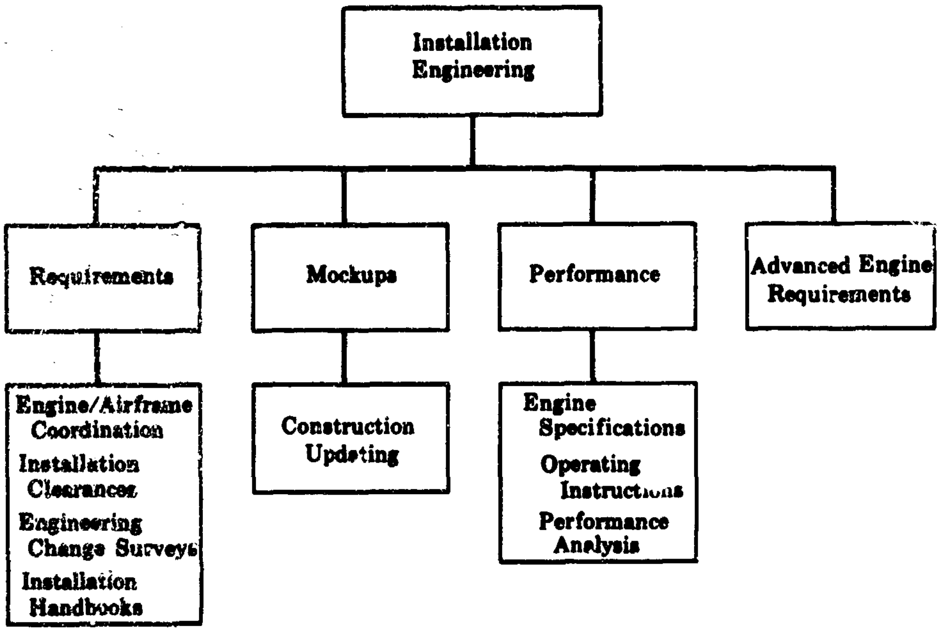


Figure 12. Installation Engineering Organization FD 17514 FVI

The Installation Requirements Group coordinates the installation design requirements for each engine model to ensure compatibility of the engine with the airframe. This group also integrates airframe requirements into the engineering development and product improvement programs which continue long after the engines enter operational service. The Installation Handbook is the responsibility of this group.

Installation Engineering personnel also coordinate with the airframe and accessory manufacturers the requirements pertaining to airframe-supplied, engine-mounted accessories.

The Installation Engine Performance Group, in conjunction with the Project Engineering Group of the Program Development organization provides the airframe manufacturer with basic engine performance, specifications and procedures for determining ground test and in-flight performance. This group also assists the airframe manufacturer by reviewing and commenting on ground and flight data acquisition and analysis during certification test programs. Operating Instructions are the responsibility of this group.

The Installation Advanced Programs Group supports the Government Products Marketing Engineers who contact the FAA and other Government agencies with technical and marketing data on advanced programs. Commercial sales engineers contacting the various airlines have received similar support from this group for the SST program.

5. Commercial Sales

This group plans, organizes and directs the sale of Pratt & Whitney Aircraft engines to the airlines and to other commercial operators.

Commercial Sales Engineers maintain continuing contact with the commercial operators, advising them of the progress of engine development and production programs and, conversely, keeping P&WA management informed of the operators requirements.

Senior men in this group have been with the company an average of 27 years; the average service experience of this group is approximately 20 years.

6. Engine Orders

This group is responsible for coordination with the customers of all aspects concerning the placement of purchase orders. Upon receipt of an airline purchase order, the Engine Orders Group issues a sales order to all departments concerned. This sales order, specifying the requirements, terms and conditions, is the mechanism which initiates procurement of the materials required to begin the manufacturing process. It is kept up to date with supplements covering all changes.

7. Product Support Department

As the engine/airframe integrated program progresses through ground test, flight test, production, delivery to the customer and into operation service, the need for product support continues. The skills and services developed by the Product Support Department during the early phases become the basis for the later phases of the program. The organization is shown in figure 13.

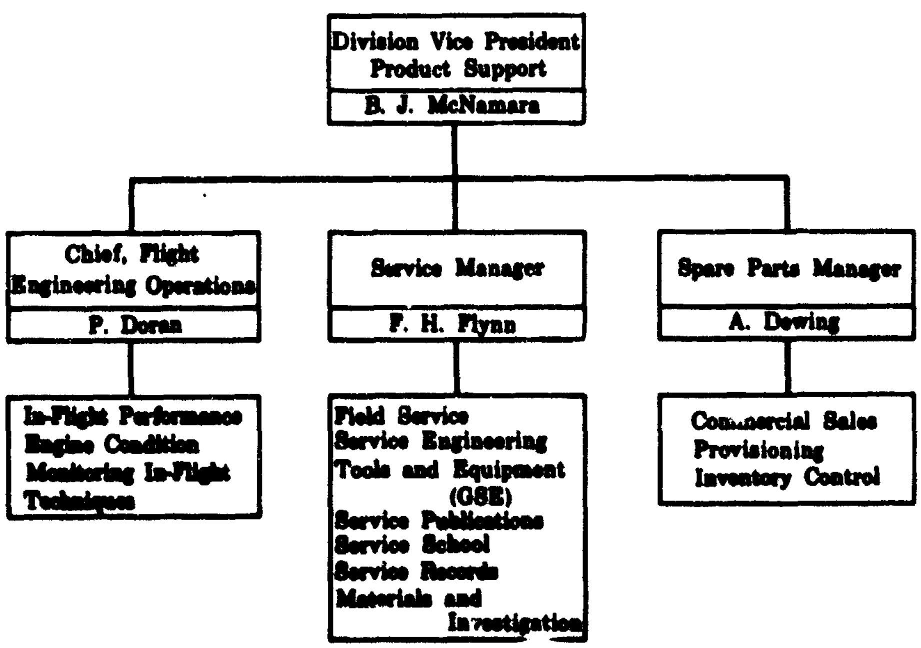


Figure 13. Product Support Organization

FD 17515
FVI

8. Service Department

The Service Department is staffed with over 840 personnel assigned to several major groups, each of which includes the specialists which experience has shown to be necessary. Of the total, approximately 320 are Field Service Representatives assigned to airframe, airline and military facilities throughout the world. The organization chart is shown in figure 14.

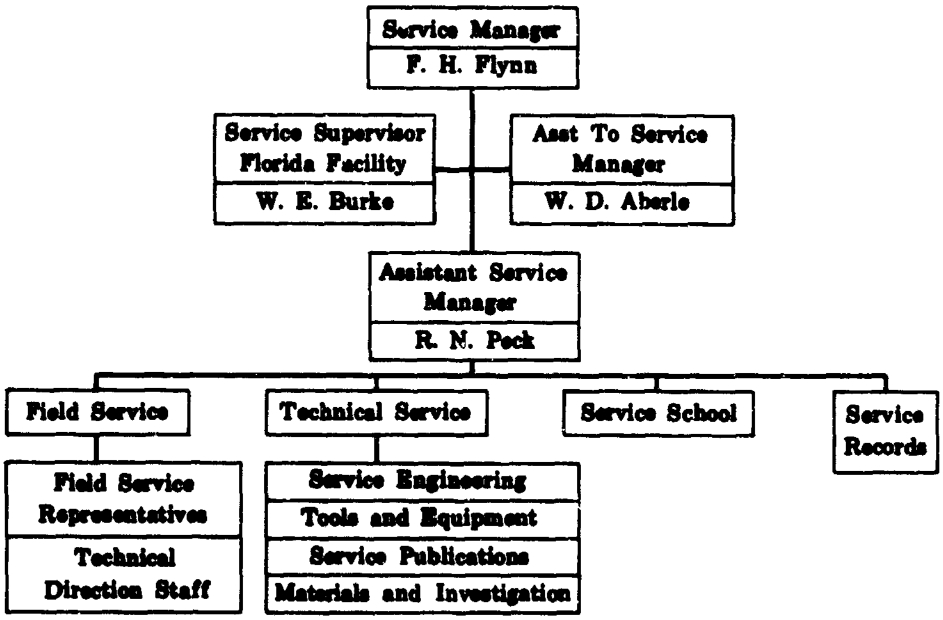


Figure 14. Service Department Organization FD 17517 FVI

9. Field Service

This group consists of Field Service Representatives and a Technical Direction staff. The function of Field Service is to assist our customers in the maintenance, overhaul and operation of Pratt & Whitney Aircraft engines. This is accomplished by experienced Field Service Representatives who provide on-the-spot coverage at the customers facilities. Average experience of representatives assigned to airframe and airline operators is 16 years.

Special attention is given to the continual training of Field Service Representatives through frequent refresher courses conducted at our manufacturing and repair facilities and at the P&WA Service School and by special briefings in the field by representatives, specifically assigned to this liaison. The Field Service Representatives also receive continuous written and oral communcations from the home office in addition to periodic visits from the liaison representatives and area supervisors to ensure that the latest information is rapidly disseminated throughout the field.

The world-wide organization is supported from the home office through a Technical Direction Staff which ensures the prompt flow of information

to the representatives and also rapidly distributes representatives reports and other pertinent field data to Management, Engineering, Safety, Reliability, Maintainability, Support, Service Record and other groups as indicated by the content of the report. This staff is composed of experienced Field Service Representatives who are selected for their understanding of the customers operations and requirements and the needs of representatives in the field.

10. Service Engineering

The Service Engineering Group provides the in-house liaison between customers and Pratt & Whitney Aircraft in technical matters affecting maintenance and overhaul. This group is the direct contact between the Field Service and the Program Engineering functions. Service Engineering issues maintenance and overhaul information to the customers as well as coordinating the flow of field experience to program management.

An important supplement to the continuing field contact by our personnel is the annual meeting of turbojet airline personnel sponsored by the Service Department at East Hartford. Problems encountered in maintenance, overhaul and repair, and experience accumulated in techniques, special procedures and operating methods, data collection, in-flight monitoring techniques and special inspection techniques by the various airlines are presented and commented on by Pratt & Whitney Aircraft engineering and service personnel. These meetings which provide an interchange of information and ideas among the airlines representatives and Pratt & Whitney Aircraft are organized and moderated by the Service Engineering Group. Approximately 190 U.S. and foreign operator representatives attended the 1965 meetings. These meetings have been conducted annually for the past 8 years.

Key members of the Service Engineering group work closely with the Program Engineering functions during the design and development of new engine models to assure that all available field and operating experience, as well as desirable maintainability features, are incorporated into the engine design.

Technical personnel in this group have had extensive experience in meeting the technical demands of the assignment. The average service of the 34 members of this group is more than 18 years.

All Engineering Change Proposals are reviewed by this group to assess their effect on retrofit, interchangeability, and maintainability. The proposed Engineering Change is approved by the Service Manager before being incorporated into production.

The Service Engineering Group also performs technical liaison functions with component vendors on matters of maintenance, repair and overhaul of vendor-supplied items such as ignition systems, fuel pumps and fuel controls.

11. Tools and Equipment

Maintenance and overhaul tools and other engine ground support equipment (GSE) are designed and provisioned by the Tools and Equipment Group. A detailed analysis of established and contemplated maintenance procedures is made on a continuing basis to ensure the compatibility of GSE and the engine.

A facility planning service for large or small maintenance and overhaul shops is available to our customers. This service is provided by a group of experienced personnel who assist in solving maintenance and overhaul problems in existing shops. This group can also lay out a complete facility tailored to the customer's particular and unique requirements.

The average experience of the 48 technical personnel in the Tools and Equipment Group is over 17 years.

12. Service Publications

Technical literature for the maintenance, overhaul, operation and logistics support of all Pratt & Whitney Aircraft engines and engine components in service use is written, published and distributed by the Service Publications Group.

The data and handbooks are published and delivered in the desired quantities and time phasing to permit training prior to the delivery of the engine.

Listed below are the manuals published by the Service Publications Group:

- Installation Handbooks
- Maintenance Manuals
- Overhaul Manuals
- Operating Instructions
- Illustrated Parts Catalogs
- Service Bulletins
- Service Instructions
- Facility Planning Manuals
- Special Engine Tool Manuals

Revisions are issued as required throughout the service life of the engines to reflect changes in engine configuration or procedures.

Commercial engine manuals follow specifications and format in compliance with FAA, ATA, and IATA requirements including ATA Specification No. 100.

Figure 15 shows the typical publications issued for the JT8D engine.

The group consists of 158 authors, illustrators, editors and supporting personnel. The technical staff has an average of over 10 years service with Pratt & Whitney Aircraft.

Figure 15. Typical Publications Issued for JT8D Engine H-59227 FVI

13. Service School

Pratt & Whitney Aircraft's customer training facility has been in continuous operation since 1935. It has gained unparalleled engine training experience from the preparation and presentation of over 250 custom-tailored courses to more than 27,000 airline, airframe, FAA and military engineers and technicians. It represents the largest training organization of its kind in the world with a permanent teaching staff of 25 professional instructors whose experience in the aviation industry averages 22 years.

Training facilities consist of 30,000 square feet of modern classrooms, amphitheaters and student workshop areas located in Wethersfield, Connecticut, within three miles of the main plant.

Figure 16 explains further the functions and teaching methods of the Service School.

Discussion
One of the Service School's many specialized teaching facilities is a large conference room. It provides an excellent atmosphere in which students and faculty can hold discussion sessions or formal meetings.

Demonstration
To help enrich classroom instruction, the Service School stocks a large inventory of actual engine parts, diagrams, charts, and mockups — all of which assist the instructor in conducting effective and interesting sessions.

Participation
In the more detailed courses, students spend a considerable amount of time in the repair and maintenance shop. Students gain first-hand experience in engine disassembly, assembly, inspection, and trouble-shooting.

Operation
An asset of "factory training" is the opportunity it affords students to utilize engine test cells and other apparatus used in the production of engines. Here students actually operate the engines they worked on during classes.

Experienced Staff
A staff of full-time instructors is well equipped to cover both theoretical and practical aspects of aircraft engine overhaul, maintenance, operation, and performance.

Complete Facilities
Extensive training facilities enable P&WA's Service School to meet widely varied training requirements, whether they involve giving a specialized course to a small group or presenting an engine symposium.

Figure 16. Pratt & Whitney Aircraft Service School

FD 16665
FVI

14. Service Engineering Records

The Service Engineering Records Group analyzes, categorizes the records of engine operation, maintenance and overhaul experience as reported by our Field Service Representatives and airline and military sources. This information is categorized by engine model in summary form and distributed to the engineering, maintainability, reliability and service groups. Much information is stored by electronic data processing equipment, making it readily available for examination and study.

In a typical year of operation, information derived from 124,000 Field Service Representatives reports, wires and other sources, is recorded by this group. A total of 2100 reports and summaries is produced from this data.

On customer request, a detailed list of part changes and possible rework of parts to modernize, convert or update engines to a desired model configuration can be furnished. This vital operation is performed by 35 analysts who average 21 years of service with the company.

15. Materials and Investigation

This group handles two categories of engine parts in complementing some functions of the Spare Parts Department, but not duplicating them. The first involves the Investigation section, which has a skilled staff of 24 specialists with an average experience of 20 years. This group examines parts returned from the field due to failure or a suspected difficulty and provides to the customer a comprehensive report of the findings and recommendations to avoid repetition of the problem.

Coordination with the Program Engineering organization is maintained through the Service Engineering Group to ensure that program personnel are aware of difficulties encountered and that corrective Engineering Change action is taken as necessary. Modern apparatus such as spectro-analysis, ultrasonic detection and X-ray is utilized during the investigation process.

The Materials section plans and expedites the procurement and distribution of parts involved in engine campaign programs and also provides the liaison with airline customers in satisfying warranty and Service Policy claims.

16. Spare Parts Department

Pratt & Whitney Aircraft has a department of approximately 200 specialists to manage its spare parts programs. The commercial operation organizational structure is shown in figure 17 followed by a brief description of its operation. Key personnel in the various groups have an average of 25 years experience with the company.

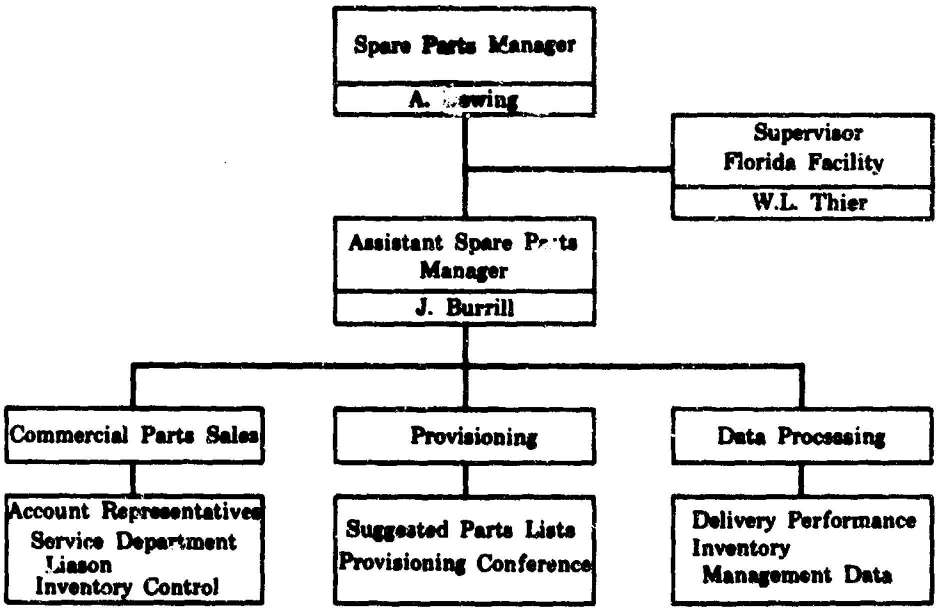


Figure 17. Spare Parts Organization

FD 17516
FVI

Close communication with customers is maintained by Account Representatives who make periodic visits to airlines logistics personnel to review parts consumption, inventory status and to assist in resolving spare parts problems.

A Spare Parts Representative is located within the Service Department to reduce reaction time to field service problems affecting spare parts requirements. Abnormal parts usage encountered by airlines is noted by Account Representatives and reported to the Service Engineering Group who review the background and determine the technical reasons for the unanticipated rate. When necessary, revised maintenance procedures

or repairs are initiated. If Engineering Change action is required to rectify the situation the program engineering organization is advised.

A Provisioning Group provides maintenance and overhaul logistic support recommendations predicated on specified customer needs. This group also organizes and conducts provisioning conferences and verifies the currency and compatibility of all items ordered by our customers.

Approximately 25,000 spare parts are maintained at Pratt & Whitney Aircraft expense in a "Service Stores Inventory" at the home plant to reduce delivery time of parts to airline customers. A "Maximum and Minimum" stock system is in effect, which involves such considerations as a world-wide monthly consumption forecast for each part, procurement lead times, economical manufacturing quantities, and intensive planning liaison and data interchange with our customers. The "Service Stores Inventory" system is designed to provide "off-the-shelf" delivery for the normal maintenance and overhaul requirements of our airline customers. Supporting world-wide airline logistics requirements is a complex operation, and no reasonable amount of contractor supported inventory can guarantee off-the-shelf delivery in every case. Short lead time capability is therefore planned for high value, low usage items and those for which demand is relatively stable. Experience has shown that 90 days is normally a practicable and acceptable delivery lead time for spare parts. In those instances requiring more time, the customer is promptly advised and every effort is made to expedite his order.

Pratt & Whitney Aircraft commercial spare parts operations utilize a IBM 1401 computer which provides delivery performance data and inventory management information rapidly and efficiently. The system is designed to accommodate customers operating under ATA Specification No. 200.

17. Flight Operations Engineering

The Flight Operations Engineering Group assists airlines and other operators in developing and maintaining practical and efficient operating techniques. This group of engineers, some with pilot's ratings, work directly with airline operations personnel observing in-flight techniques and analyzing engine performance. Direct participation in the initial flight training, delivery and route proving flights is provided during the introduction of new equipment to airlines. Subsequent periodic flights are made to ensure incorporation of the latest engine management procedures and to review engine performance.

An important activity of this group has been the development of various turbine engine condition monitoring techniques, including the Airborne Integrated Data System, in conjunction with various airlines and committees.

The 15 Flight Operations Engineers comprising this group have an average of 20 years with Pratt & Whitney Aircraft.

SECTION VII
WEIGHT CONTROL

A. OBJECTIVE

The objective of the Weight Control function in the JTF17 program is to minimize engine weight consistent with overall engine design requirements and objectives. Implicit in this function are comprehensive and timely reporting of status to program management, accurate assessment of the weight effect of all variables, and aggressive pursuance of weight reduction possibilities. Explicit objectives for the weight control program for Phase III are as follows:

1. Continuously update engine weight status
2. Periodically report engine weight status to program management
3. Originate and/or pursue weight reduction changes
4. Set target weight breakdowns for motivation of designers
5. Perform weight trade studies between design alternatives.

B. ORGANIZATION AND RESPONSIBILITIES

The weight control function of the JTF17 program is performed by the Design Weight Group, reporting to the Chief of Analytical Design. This group is made up of experienced weight engineers and computists with backgrounds on all FRDC projects, current and advanced. The efforts and accomplishments of this organization during Phase II are exemplified by the weight report of Volume III, Report A, Section IV.

1. Extent of Coverage

The extent of coverage by the design weight control group in Phase III of the JTF17 program is described by reference to overall group responsibilities and procedures. Included are references to Phase II activities and the transition into Phase III. Weight Group functions to be described are:

- Records
- Control
- Design Trade Studies
- Parametric Studies
- Design Loads

a. Weight Records

Weight status of prototype design during Phase II has been reported monthly. The system that provides the continuous updating will perform the same function in greater detail during Phase III.

The Phase II weights have been calculated and updated on the basis of design layouts or sketches to keep pace with the fluid early stage of engine design. Phase III and later Phase II engine weight calculations use the increasingly available detail drawings. Weight calculations on detail drawings are initiated by Drafting using the weight request form of figure 1. Add-cancel lists, prepared by design analysts for particular design changes, are used where available. In other cases, weight engineers interpret the design, for the computist, in terms of net weight effect on overall engine design. Upon issuance of engineering change proposals, weight changes are calculated and made a part of the EC description as illustrated by the J58 engineering change of figure 2.

Florida Research and Development Center

REQUEST FOR WEIGHTS

Engine Model________________ Drafting Job No.________________

Lead Draftsman____________ Phone__________ Date Sent____________

Design Analysts____________ Phone__________ Date Returned____________

No. of Prints Delivered with this Request: New_____ Revised__________

Are those parts in the Parts List?______________________________

Layout No.________________ No. of Sheets____________

If a Job is on an Engineering Change or RCID, Fill in the Following:

Engineering Change No.________________

Nature of Change______________________________

____

____

____

____

Disposition:

______________ Must Conform

______________ Use Parts on Hand & In Process

______________ Incorporate By____________ Engine

Be sure to give total number of units per engine for each detail part listed on the change.

To Be Filled In by Weight Group:

Date Recorded________________ ΔW________________

Date Finished________________ By________________

For Departmental Use Only

PWA-FRDC

Figure 1. Weight Request Form FVII

DEVELOPMENT (CLASS IB)
ENGINEERING CHANGE IN DESIGN

Pratt & Whitney Aircraft

DIST. CODE F-1
DATE ISSUED E.M.
CHANGE NO. 173002 SUPP.
PROPOSED BY Engineering(L. Hanner) DATE ISSUED 2-1-66 PAGE NO. 1 NO. OF PAGES 2

MODELS AFFECTED
AIR FORCE J58
NAVY
COMMERCIAL

NATURE AND REASON

Provide new Insulation Blanket for the number two Bearing.

To provide a more durable insulation blanket with better insulation properties.

Substantiating test data: FX116-28 & 29 for 435.53 hours.

THIS CHANGE MUST BE INCORPORATED IN NEW ORDER J58 ENGINES NOT LATER

EFFECT OF CHG. ON			
MODEL SPEC.	No	TARGET PRICE OF MODEL SPARES	No
PERFORMANCE	No	STRENGTH OR DURABILITY	No
CONTRACT PERFORMANCE	No	CENTER OF GRAVITY	No
ENGINE WEIGHT	Δ W= +.4008	INTERCHANGEABILITY	No
CONTRACT WEIGHT		INSTALLATION	No
NEW PART NOS. REQ'D.	Yes	REASON SEE PAGE	2
RECORD OF DWG. NOS. REQ'D.	Yes	PATTERNS OR DIES AFFECTED	See Above
RECORD OF ITEM SERIAL NOS. REQ'D.	No	SUBSTANTIATING TEST DATA REQ'D.	No
TABLE OF LIMITS AFFECTED	No	SERVICE RECOMMENDATIONS	No
ASSY. PARTS LIST AFFECTED	Yes	CLEARANCE INDEX CHART APP'D.	No
ASSEMBLY DWGS AFFECTED MAJOR	Yes	OBSOLETION OF DWG. REQ'D.	See Page 2
INSTALLATION DWGS AFFECTED	No	SITE AFFECTED	No
ASSEMBLY/DE REQUIRING NE DWG. CHG.	None		
SUPERSEDED PARTS RETAINED FOR SPARES	No		

ENDORSEMENTS

CHANGE NO. 173002 SUPP.
PAGE NO. 2 NO. OF PAGES 2

DISPOSITION OF MATL.: SEE COLUMN AT RIGHT BELOW. THE CHANGE APPLIES TO ENGINE-PARTS & SPARES UNLESS OTHERWISE NOTED BELOW.

PART NO.	NEW CHG. DEL.	PART NAME	MODELS	
2077997 Sh 1	$	Compressor Assy	J58	
2114397 Sh 1	$	Compressor Assy	J58	

$ WILL FOLLOW
Revise drawings 2077997 & 2114397, sheets 1, in accordance with the marked transparency of 2114397.

Per J58 Engine

Add	Units		Cancel	Units	
	Ref	Compressor Assy			
2102903	1	Shield - Ht, No. 2 Brg. Foil, Assy	2080357	1	USE
2102907	1	Insulation Blanket - No. 2 Brg	2080445	1	USE
2102904	1	Shield - Ht, No. 2 Brg. Foil, Assy	2080359	1	USE
2102908	1	Insulation Blanket - No. 2 Brg	2080447	1	USE
2102905	1	Shield - Ht, No. 2 Brg. Foil, Assy	2080360	1	USE
2102910	2	Insulation Blanket - No. 2 Brg	2080448	1	USE
2102906	1	Shield - Ht, No. 2 Brg. Foil, Assy	2080358	1	USE
2102909	1	Insulation Blanket - No. 2 Brg	2080446	1	USE

Assy Parts List Affected: 2077997 & 2114397.
Reason for new part numbers: Superseded and superseding items are not directly and completely interchangeable with respect to installation and performance.
Obsoletion of drawings: Consider drawings 2080357, 2080358, 2080359, 2080360, 2080447 and 2080448 for obsoletion upon incorporation of this change. Consider drawings 2080445 and 2080446 for cancellation from production upon incorporation of this change.

Figure 2. Engineering Change in Design

Weight calculations are facilitated by numerous essential references and handy aids exemplified by the material density chart of figure 3 and the integral ferrule weight chart of figure 4. All detail part weights are recorded by the weight group on the weight data sheet of figure 5 and supplied to Engineering Records on the computer input form of figure 6. A complete file of all part weights on all projects is maintained in numerical order by Engineering Records as illustrated in figure 7. Actual part weights are provided to the Weight Group by Finished Stores for comparison to calculated values. This provides a means of continuous reassessment of calculating procedures. Engineering Changes, with the weight of each part affixed, are retained in permanent weight group files. Monthly weight updates utilize these EC weight changes. Confirmation is gained from periodic "weight runoffs" or matching of current parts list with the detail part weight file. These runoffs are presented by assembly and by material as illustrated in figures 8 and 9, respectively. These are current procedures on all FRDC programs including the J58 and RL10 programs.

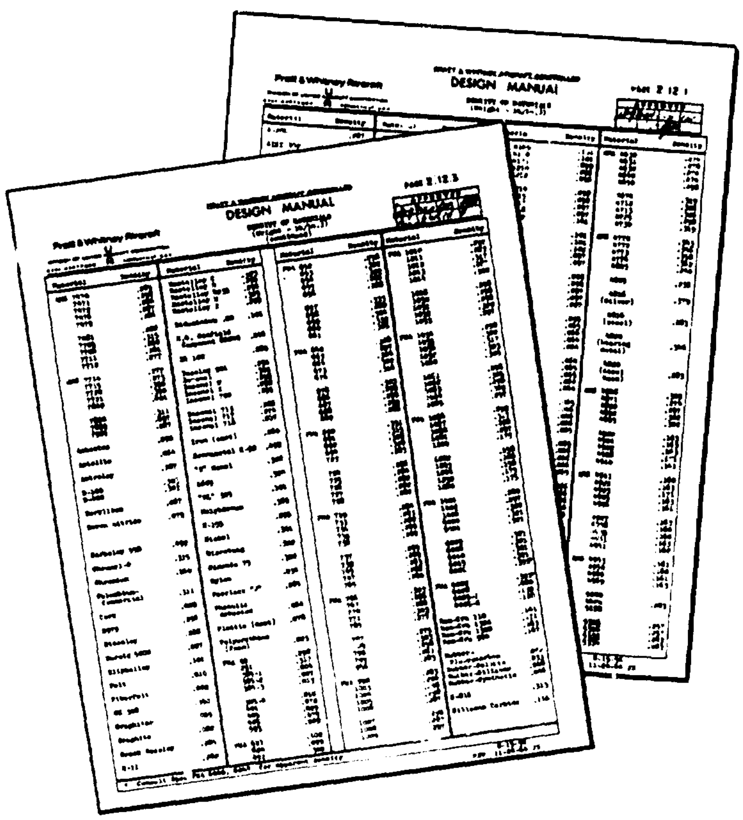
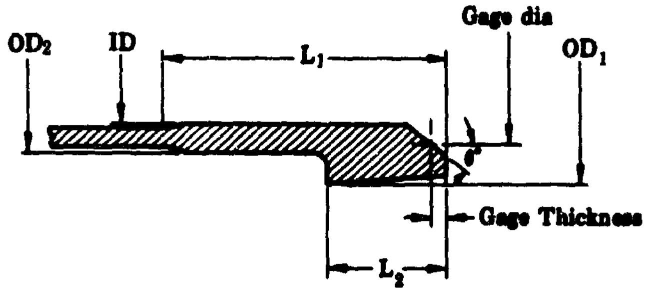


Figure 3. Design Manual: Density of Materials

FD 17727
FVII



	Tube OD (Max)	OD_2 (Max)	ID (Min)	L_1	L_2	θ	Gage Dia	Gage Th	OD_1 (Max)	1-770 Wt	1-1060 Wt
1	0.376	0.396	0.287	0.620	0.238	37°	0.358	0.041	0.502	0	0.016
2	0.376	0.391	0.287	0.660	0.315	37°	0.504	0.054	0.682	0.016	0.017
3	0.376	0.396	0.287	0.660	0.238	37°	0.358	0.041	0.502	0.016	0.017
4	0.501	0.515	0.383	0.660	0.295	37°	0.504	0.054	0.682	0.027	0.029
5	0.751	0.797	0.602	0.800	0.150	37°	0.769	0.064	0.963	0.060	0.064

Figure 4. Integral Ferrule Weight Chart FD 17738
FVII

PWA - FLORIDA RESEARCH AND DEVELOPMENT CENTER

WEIGHT DATA SHEET

No.	Title	Weight	E-W	DWC	IN	Material	Pre-Weight	E-W	Date	Chg. Ltr.
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										

Figure 5. Weight Data Sheet FVII

PWA 10341 D

DETAIL WEIGHT INFORMATION AND OR CORRECTIONS
COMPILED IN WEIGHT GROUP IN
Florida Research & Development Center

NOTE: IF A DWG. IS CARTWHEELED PLACE AN "X" IN DWC COLUMN

DATE	PART NAME				PART NUMBER	CHANGE LETTER	PREVIOUS WEIGHT	PRESS WEIGHT	MATERIAL
1 - 8	12 - 38	46	47		48 - 56	57 - 61	64 - 69	70 - 75	76 - 80

Figure 6. Computer Input Form FVII

P W A - F-0004-F

ENGINEERING FINISHED WEIGHT FILE

PRATT & WHITNEY AIRCRAFT - FLORIDA RESEARCH AND DEVELOPMENT CENTER - UNITED, FLORIDA

12-07-65

PAGE 107

DWC	PART NUMBER	PART NAME	WEIGHT FINISHED WT			MATERIAL SPEC	PREVIOUS WEIGHT		CHANGE LETTER	DATE	REMARKS
	2034071	SEAL	110		W					11-28-60	
X	2034072	SEAL-FUEL PUMP	010		E P					11-04-59	
	2034075	SEAL-TURB ROT	016		W P		012			3-28-61	
X	2034078	SEAL-FUEL PUMP	008		E P					11-04-59	
	2034079	SEAL-FP IMPLR	004		E F					10-26-59	
	2034080	SEAL-TURB RTR	150		W 2	5663	145		A 2	2-22-62	
	2034082	SEAL ASSY	080		W		070			4-03-62	
	2034130	SHROUD SEGMENT	170		W 2	5504	150			4-05-61	
	2034131	SHROUD SEGMENT	170		W 2	5504	160			4-05-61	
	2034132	SHROUD SEGMENT	170		W 2	5504	160			4-05-61	
	2034133	SHROUD SEGMENT	400		W 2	5504				8-23-60	
	2034134	SHROUD SEGMENT	400		W 2	5504				8-23-60	
	2034135	SHROUD SEGMENT	395		W 2	5504	400			8-23-60	
	2034136	SEAL CPR	025		W 2	5504	030		3	12-08-60	
	2034137	SEAL CPR	030		W 2	5504	027		3	12-01-60	
	2034138	SEAL CPR INLET	031		W 2	5504	030		1	12-01-60	
	2034139	SEAL CPR INLET	030		W 2	5504	029		1	4-05-61	
	2034166	BRACE CPR INLET	140		W 2	5504	130		1	12-01-60	
	2034167	BRACE CPR INLET	136		W 2	5504	133			12-08-60	
	2034168	BRACE CPR INLET	140		W 2	5504	130		1	4-05-61	

Figure 7. Engineering Records Finished Weight File FVII

361 07/22/66

PART NAME	PART NO	E/M	ITEM	SPEC	UNITS	UNIT WT.	TOTAL WT.	JTF17A-20
SHIELD-HEAT EXH NOZ SEG FOIL								2127679
SHIELD-HEAT,EXH NOZZLE SEG,F	2127680	E	0010	2-5540	32	.077	2.464	2127679
SHIELD-HEAT,EXH NOZZLE SEG,F	2127681	E	0020	2-5540	32	.086	2.752	2127679
INSULATION FELT-EXHAUST NOZZ	2127682	E	0030	1-3955	32	.027	.864	2127679
GROMMET-EXHAUST NOZZLE SEGM	2122058	E	0040	2-5540	64	.001	.064	2127679
GROMMET-EXHAUST NOZZLE SEGME	2122060	E	0050	2-5540	480	.002	.960	2127679
							TOTAL WEIGHT 7.104 *	NON WEIGHT .000 *
GUIDE-EXH NOZZLE SEGMENT STD								2127683
GUIDE-EXHAUST NOZZLE SEGMENT	2122081	E	0010	1-1204	16	.086	1.376	2127683
NUT-SELF-LOCK,CLINCH,.250-28	2105376	E	0020	2-5709	32	.007	.224	2127683
							TOTAL WEIGHT 1.600 *	NON WEIGHT .000 *
GUIDE-EXH NOZZLE SEGMENT STD								2127684
GUIDE-EXHAUST NOZZLE SEGMENT	2122082	E	0010	1-1204	16	.086	1.376	2127684
NUT-SELF-LOCK,CLINCH,.250-28	2105376	E	0020	2-5709	32	.007	.224	2127684
							TOTAL WEIGHT 1.600 *	NON WEIGHT .000 *
GUIDE-EXH NOZZLE SEGMENT STD								2127685
GUIDE-EXHAUST NOZZLE SEGMENT	2122083	E	0010	1-1204	16	.086	1.376	2127685
NUT-SELF-LOCK,CLINCH,.250-28	2105376	E	0020	2-5709	32	.007	.224	2127685
							TOTAL WEIGHT 1.600 *	NON WEIGHT .000 *
GUIDE-EXH NOZZLE SEGMENT STD								2127686
GUIDE-EXHAUST NOZZLE SEGMENT	2122084	E	0010	1-1204	16	.086	1.376	2127686

Figure 8. Runoff Presented by Assembly FVII

66 07/22/66

PART NAME	PART NO	E/M	SPEC	UNITS	UNIT WT.	TOTAL WT.	JTF17A-20	
DISK-COMPRESSOR,8 STAGE	2116529	E	1-1016	1	59.332	59.332		
DISK-COMPRESSOR,7 STAGE	2116548	E	1-1015	1	59.630	59.630		
TIE ROD-COMPRESSOR	2117795	E	1-1016	24	.810	19.440		
TIE ROD-COMPRESSOR	2117820	E	1-1016	24	.119	2.856		
DISK-COMPRESSOR,3 STAGE	2122303	E	1-1016	1	92.362	92.362		
BOLT-MACHINE,.250-28 X .750,	2126500	E	1-1016	32	.022	.704		
						TOTAL WEIGHT 456.036 *		NON WEIGHT .000 *
HINGE-THRUST REVERSER DEFLEC	2121904	E	1-1018	2	17.142	34.284		
SEAL-THRUST REVERSER DEFLECT	2121908	E	1-1018	2	4.576	9.152		
HINGE-THRUST REVERSER DEFLEC	2125950	E	1-1018	2	17.142	34.284		
						TOTAL WEIGHT 77.720 *		NON WEIGHT .000 *
SPRING-FINGER VALVE,AB,CC DR	2059369	E	1-1030	1	.006	.006		
GUIDE-AB NOZZLE	2079009	C	1-1030	64	.030	.920		
SEAL RING-METAL,2.570X.081X,	2087590	E	1-1030	1	.016	.016		
						TOTAL WEIGHT 1.942 *		NON WEIGHT .000 *
CASE SEGMENT-INTERMEDIATE	2114609	F	1-1033	1	.947	.947		
CASE SEGMENT-INTERMEDIATE	2114610	E	1-1033	1	.761	.761		
CASE SEGMENT-INTERMEDIATE	2114611	F	1-1033	6	.851	5.106		
RING SEGMENT-CC INLET DEFL,1	2114765	E	1-1033	12	.326	3.912		
PLATE-FAN STATOR,VANE STOP	2115122	F	1-1033	2	.021	.042		
WASHER-SPCT,A.000X.1525X.029	2115276	E	1-1033	2	.035	.070		
SUPPORT-NO 4 BEARING AIR SLG	2115327	E	1-1033	1	3.033	3.033		

Figure 9. Runoff Presented by Material FVII

b. Weight Control

Control of engine weight in the JTF17 program depends on two major factors: (1) continuous assessment of weight status relative to a realistic target, and (2) specific weight reduction recommendations.

The motivational value of target weights depends on each designer's recognition of realistic goals. This recognition of goals calls for a sectional weight breakdown corresponding to the responsibilities of particular design groups. Realistic goals further call for a target weight breakdown that assigns target reductions where these reductions are most feasible, i.e., recognition of weight problem areas. Weight reduction recommendations can originate at any point and from any source in the JTF17 program. Ideas originating in the weight control group spring from trade studies, comparisons to other engines, or simply from weight-oriented thinking. Regardless of origin, the responsibility for investigating and proving feasibility rests with the Weight Control Group.

c. Design Weight Trade Studies

Weight trade studies during Phase III will, by nature, compare detailed design alternatives. Direct comparisons will be made, using design layouts or sketches. Where alternatives are sufficiently similar, weight differences are calculated by reference to design differences rather than by comparison of absolute numbers obtained from separate analyses of the alternative designs. Experience in Engineering Change weight calculations on other projects is beneficial in that the availability of comparable part weights has provided the opportunity to perfect weight comparison techniques. This was true particularly in the earlier trade studies during Phase II, which involved more fundamental but less detailed comparisons, such as evaluation of alternative airfoil chords, rotor speeds, materials, and structural configurations. Extensive side effects, such as rotor critical speeds, cooling air rerouting and mount load effects were included in the weight considerations. Thus the experience of weight engineers on other projects and the availability of related weight data have been indispensable in these weight studies. Particular weight study results are referenced in Volume III, Report A, Section IV.

d. Parametric Weight Studies

Still earlier in the JTF17 program, parametric weight studies were involved in cycle selection and initial configuration definition. Weight comparisons used design layouts and sketches whenever available but depended most heavily on analytical calculations and empirical data from previous experience. Typical variables were airflow, compressor or turbine inlet temperatures, pressure ratios, rotor speeds, airfoil aspect ratios and bearing-shaft configurations. Parametric studies during Phase III will be limited primarily to growth projections.

e. Design Loads

The weight control group supports the designer by providing design load data. This function is facilitated by calculating aids and computer

programs as exemplified by the form of figure 10. These data include the following:

1. Rotor blade centrifugal loads for use in disk and attachment design
2. Rotor centers of gravity and moments of inertia and subsequent bearing and mount loads corresponding to both g-load and gyro conditions
3. Engine center of gravity and moment of inertia and subsequent mount loads
4. Engine and rotor shear and moment diagrams.

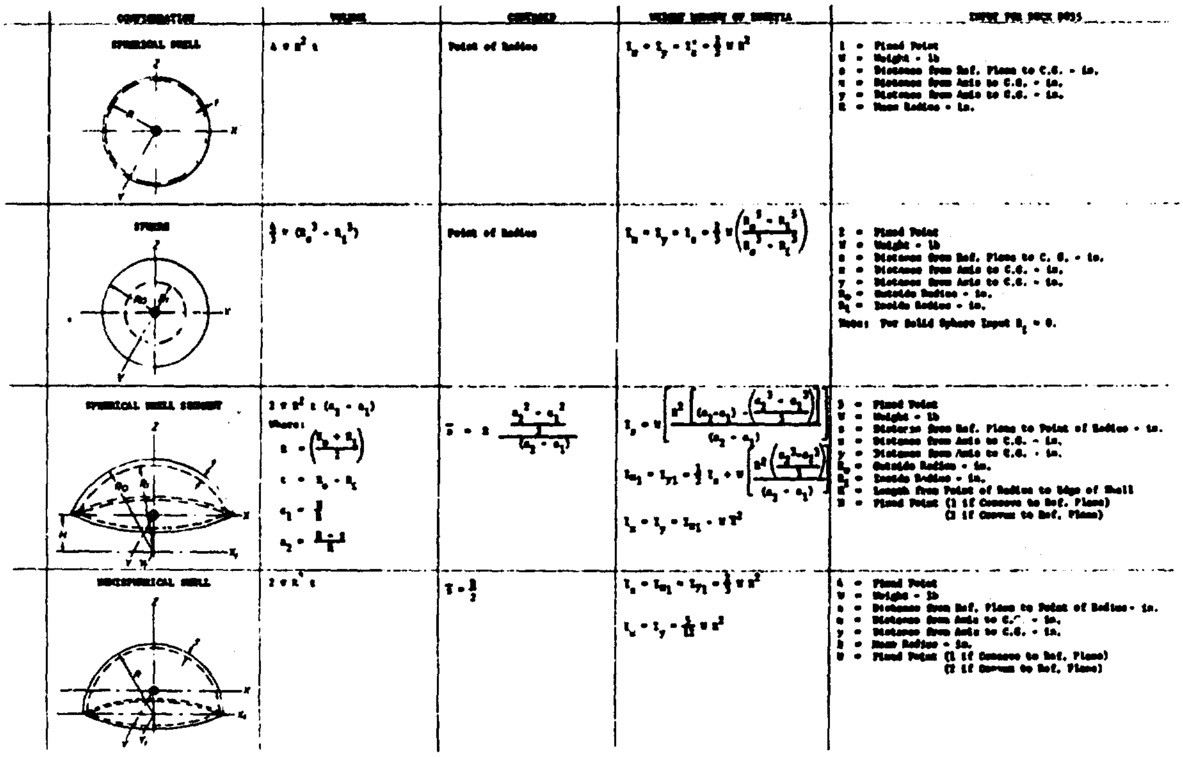


Figure 10. Design Load Data Calculating Aid FVII

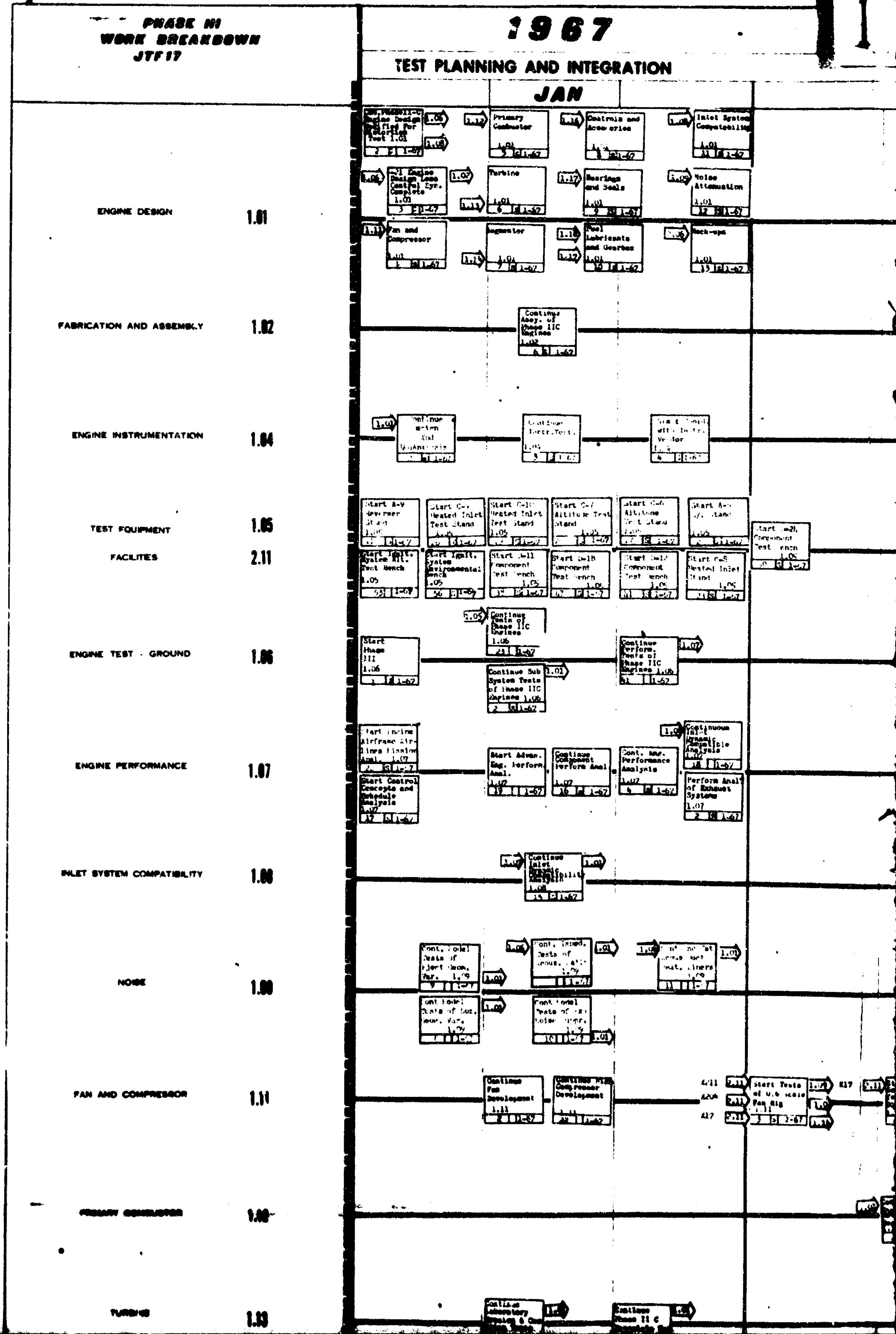
2. Phase III Tasks

The overall weight control procedures and responsibilities for Phase III include the following specific tasks:

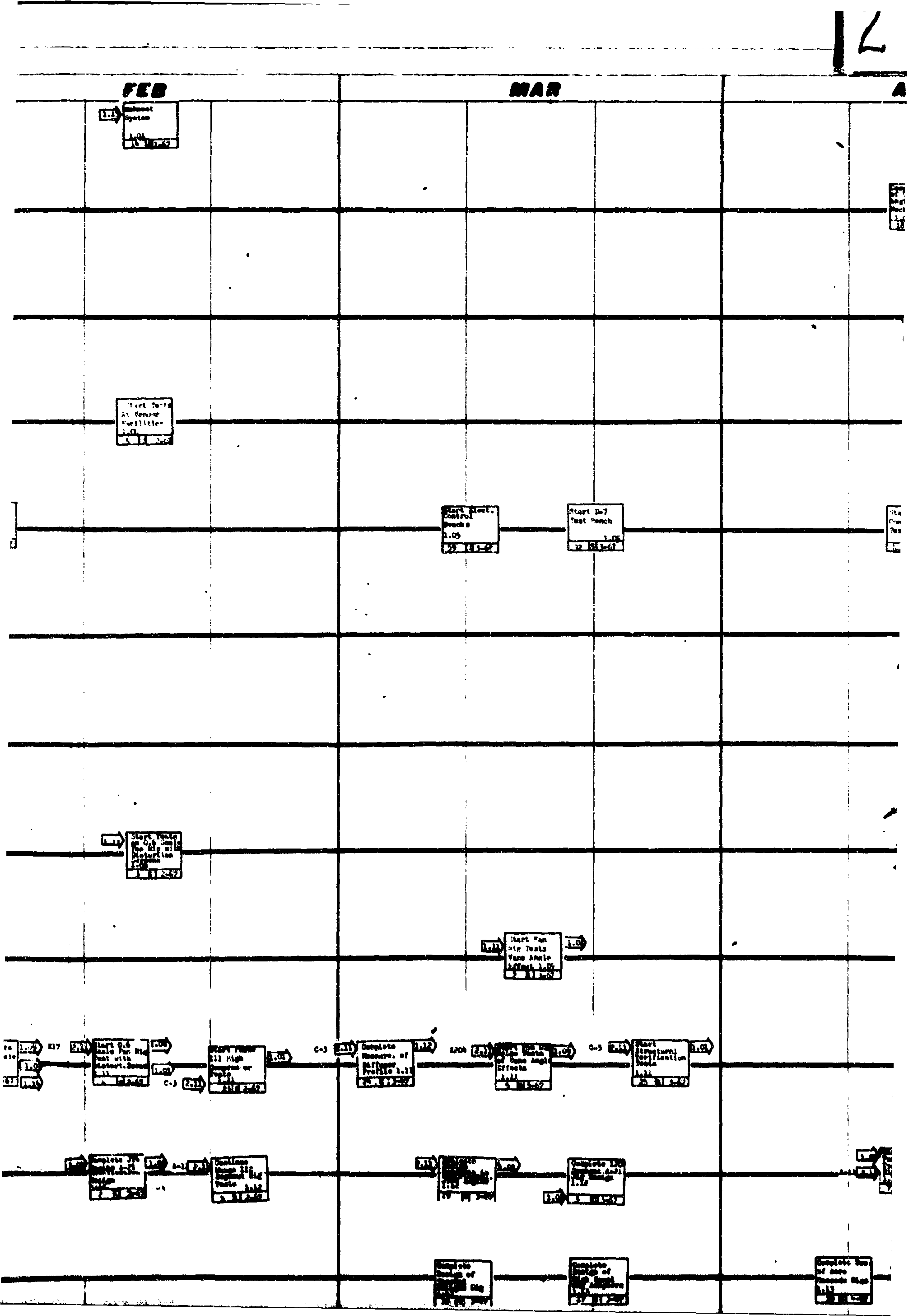
1. Issue a monthly Weight Report including current status, progress relative to target, and listing of weight reduction possibilities
2. Provide in Engineering Records, the weight of every detailed engine part
3. Provide, as an integral part of every engineering change, the net engine weight effect of the EC
4. Provide up-to-date values of engine weight, center of gravity and moment of inertia for installation drawings and handbooks.

Pratt & Whitney Aircraft
FLORIDA RESEARCH AND DEVELOPMENT CENTER

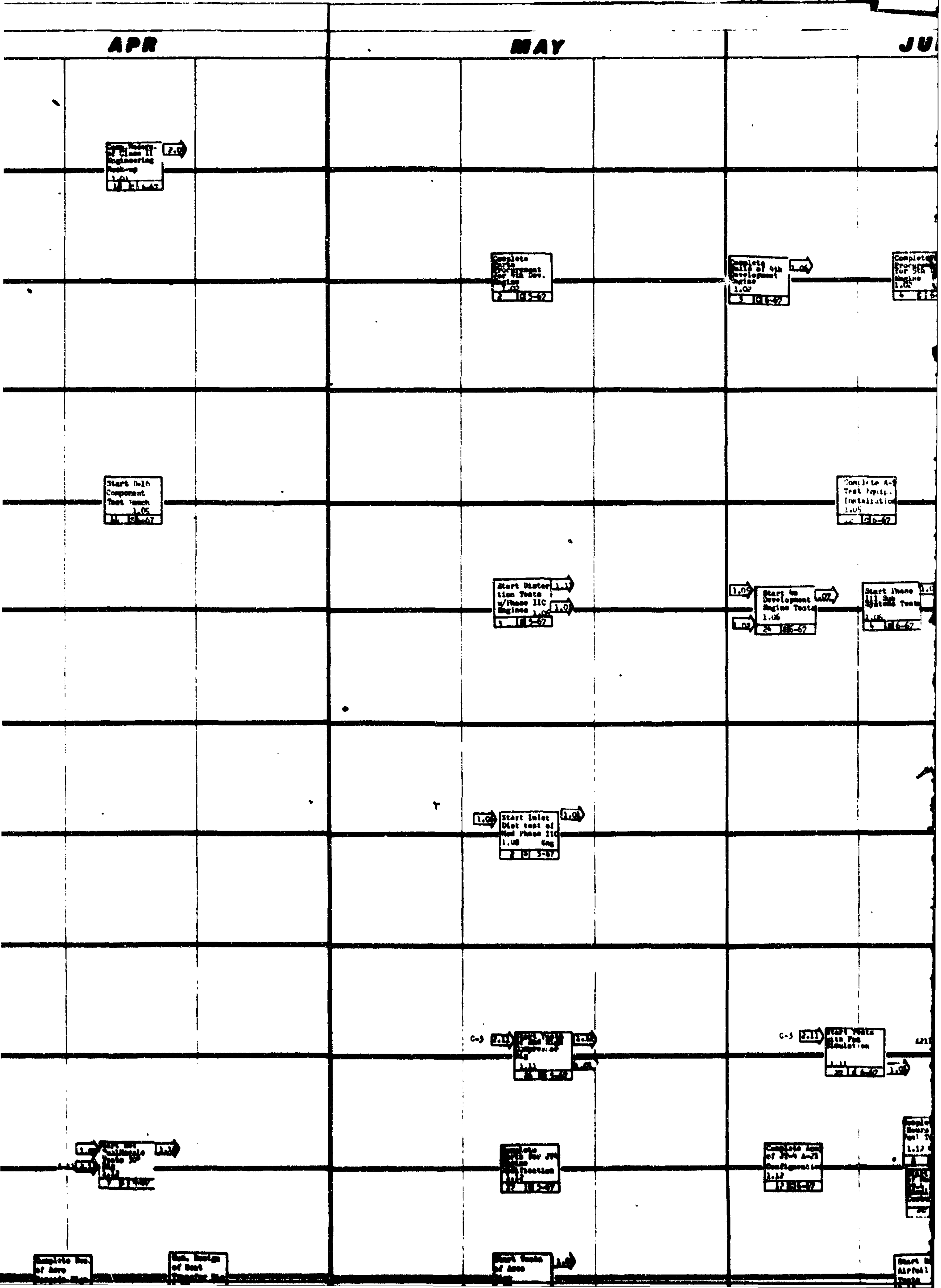
U
A®



PHASE III
WORK BREAKDOWN
JTF17
1967
TEST PLANNING AND INTEGRATION
JAN
ENGINE DESIGN 1.01
Primary Combustor
Inlet System Compatibility
Turbine
Bearings and Seals
Noise Attenuation
Fan and Compressor
Augmentor
Fuel Lubricants and Gearbox
Mock-ups
FABRICATION AND ASSEMBLY 1.02
Continue Assy. of Phase IIC Engines
ENGINE INSTRUMENTATION 1.04
TEST EQUIPMENT 1.05
FACILITIES 2.11
Start A-9 Reverser Stand
Start C-10 Heated Inlet Test Stand
Start C-7 Altitude Test Stand
Start C-6 Altitude Test Stand
Start Ignit. System Environmental Bench
Start Phase III
Continue Sub System Tests of Phase IIC Engines
ENGINE TEST - GROUND 1.06
ENGINE PERFORMANCE 1.07
Start Control Concepts and Schedule Analysis
Start Advan. Eng. Perform. Anal.
Cont. Eng. Performance Analysis
Perform Anal. of Exhaust Systems
INLET SYSTEM COMPATIBILITY 1.08
NOISE 1.09
FAN AND COMPRESSOR 1.11
Continue Fan Development
PRIMARY COMBUSTOR 1.12
TURBINE 1.13


FEB
MAR
Start Tests
At Vendor
Facilities
Start Elect.
Control
Bench
1.05
Start D-7
Test Bench
Start Fan
Rig Tests
Vane Angle
Effect
Start Structural
Verification
Tests
Complete
Measure. of
Diffuser
Profile
Complete
Design of
Aero
Cascade Rigs

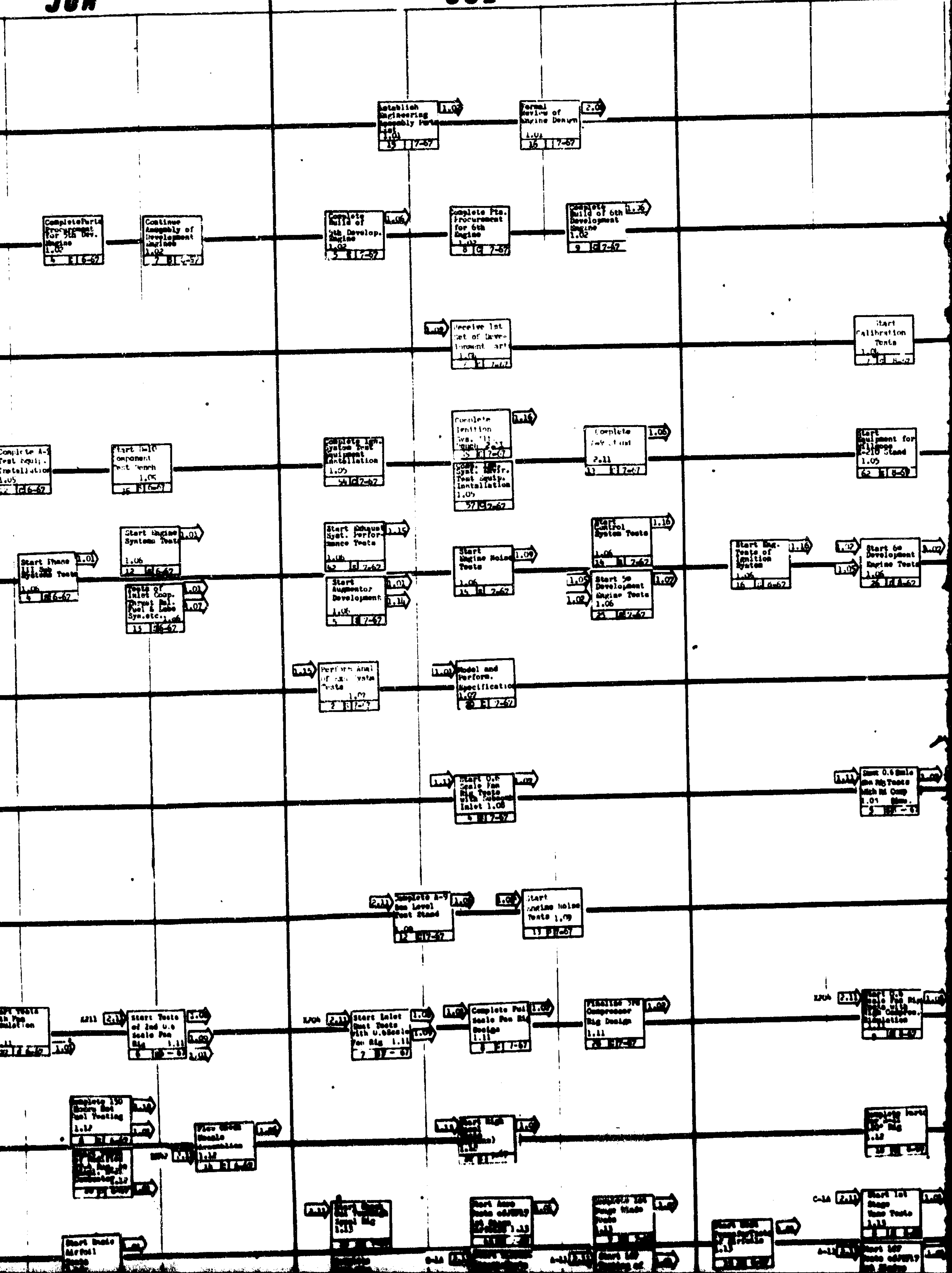
TEST PLAN 3


APR
MAY
JU
Start D-16 Component Test Bench 1.05
Complete Parts Procurement for 4th Dev. Engine 1.02
Complete Build of 4th Development Engine 1.02
Complete A-9 Test Equip. Installation 1.05
Start Distortion Tests w/Phase IIC Engines 1.06
Start 4th Development Engine Tests 1.06
Start Phase III Sub Systems Tests 1.06
Start Inlet Dist test of Mod Phase IIC Eng 1.08
Start Tests with Fan Simulation 1.11
Complete Assy of JT-4 A-21 Configuration 1.12

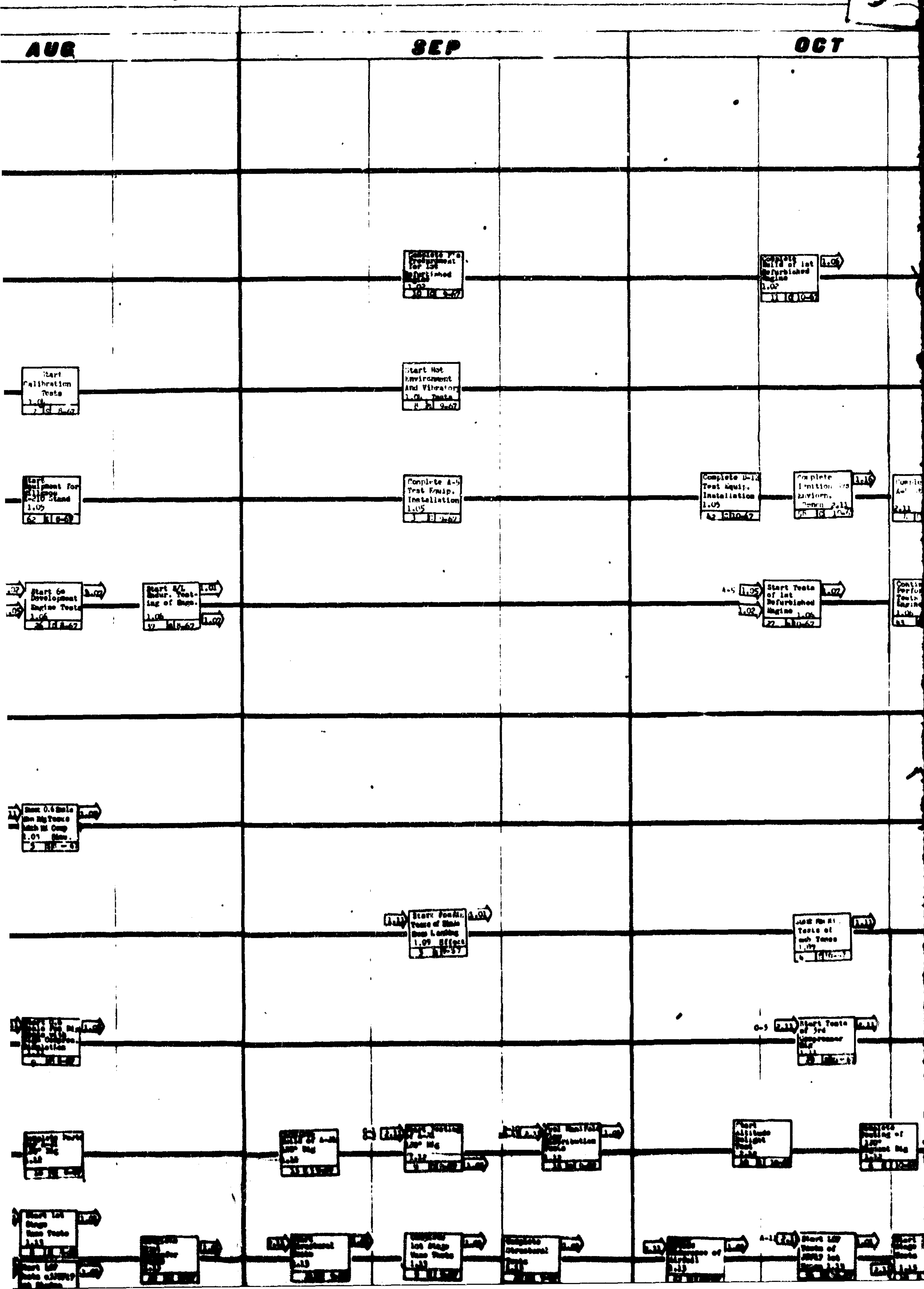
NNING AND INTEGRATION

1967

JUN JUL AUG

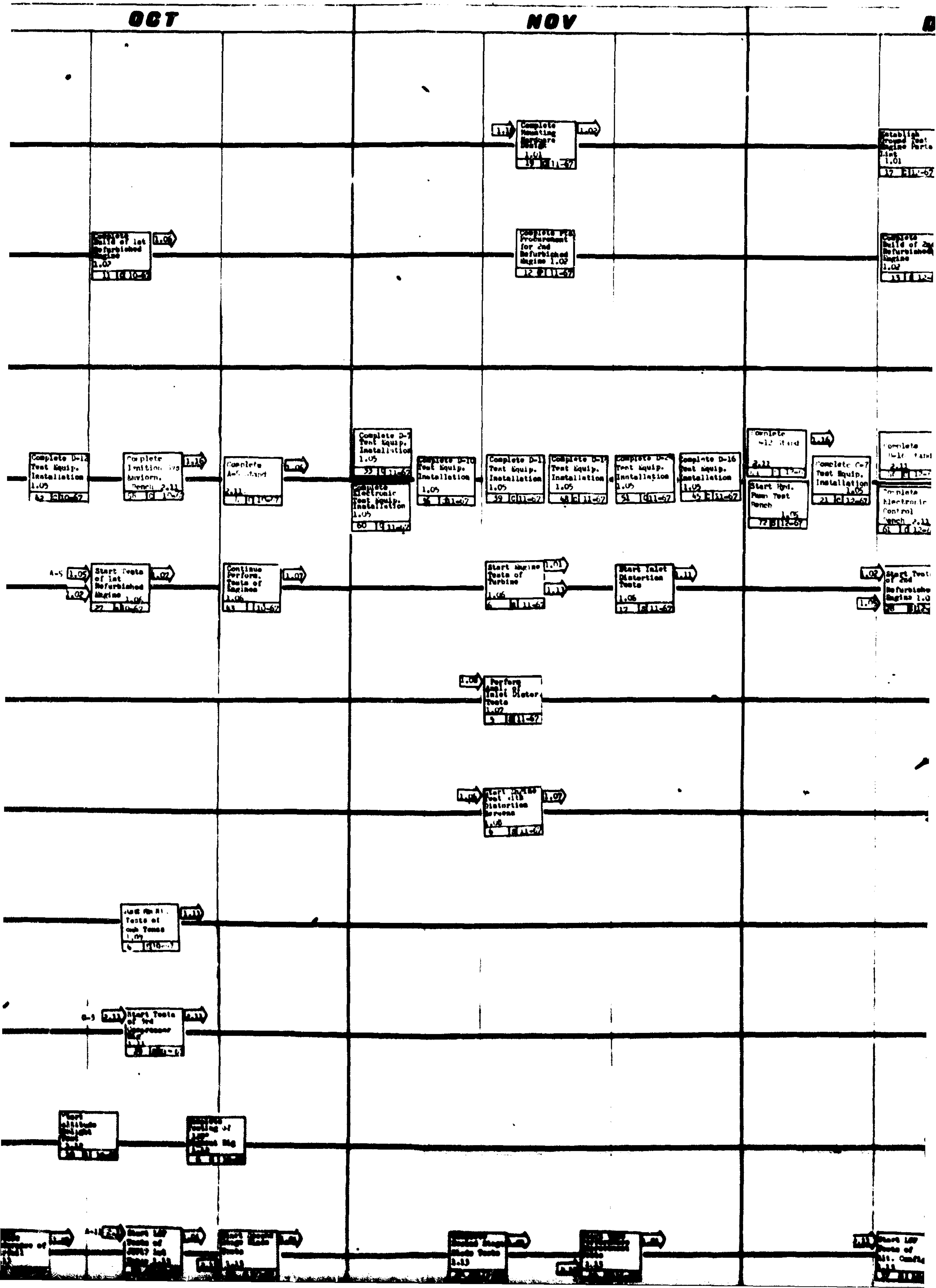


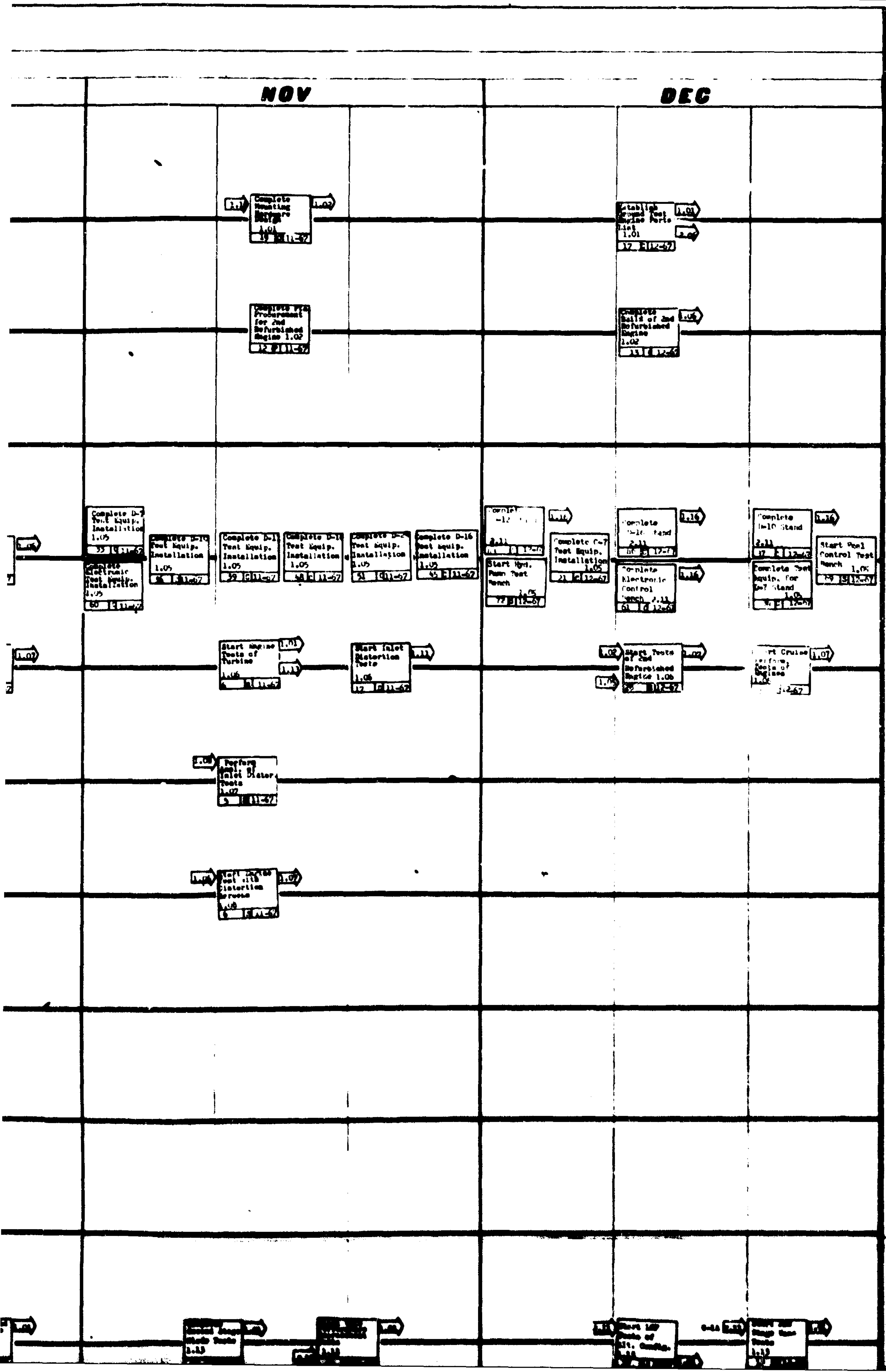
5

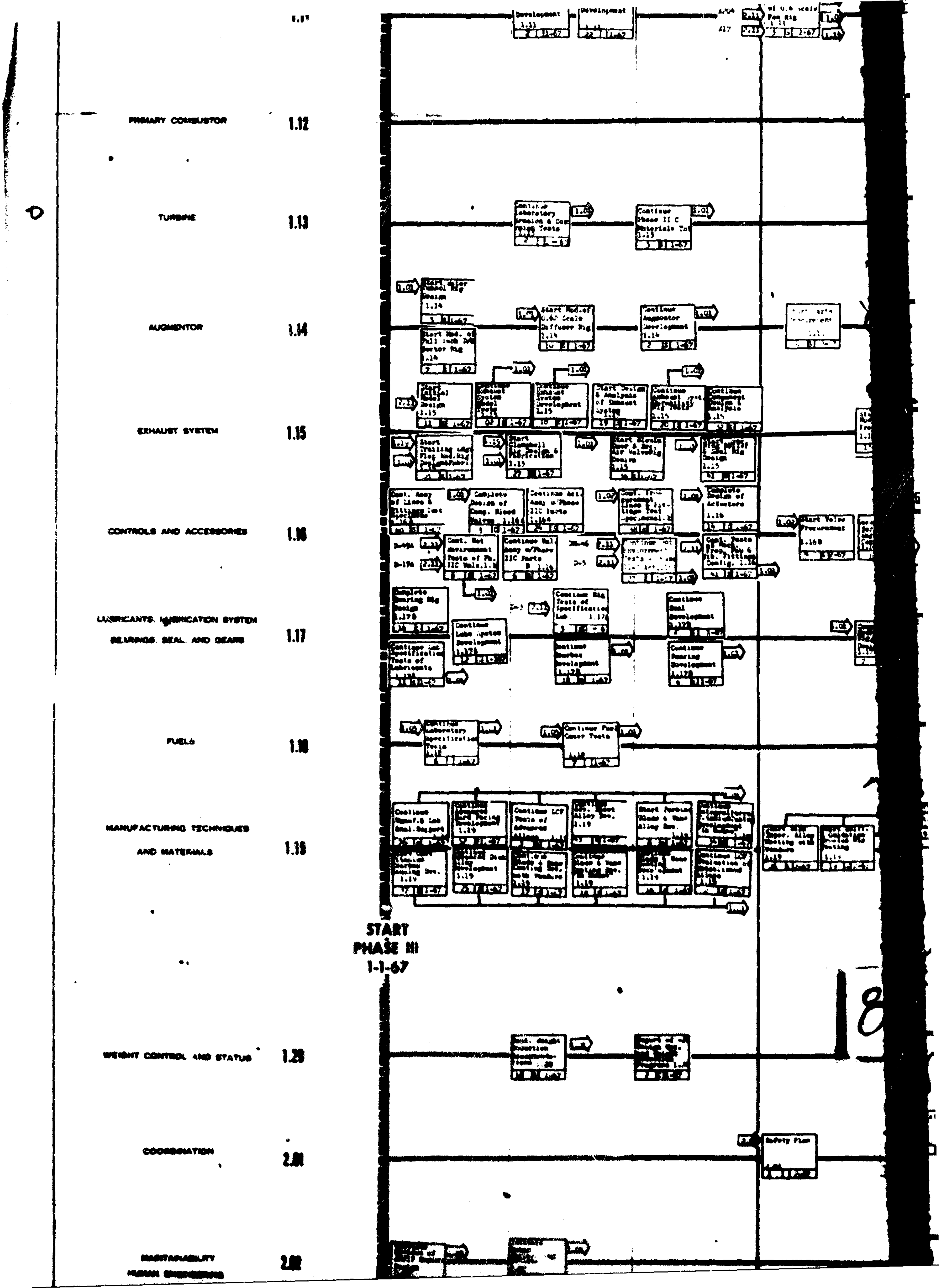


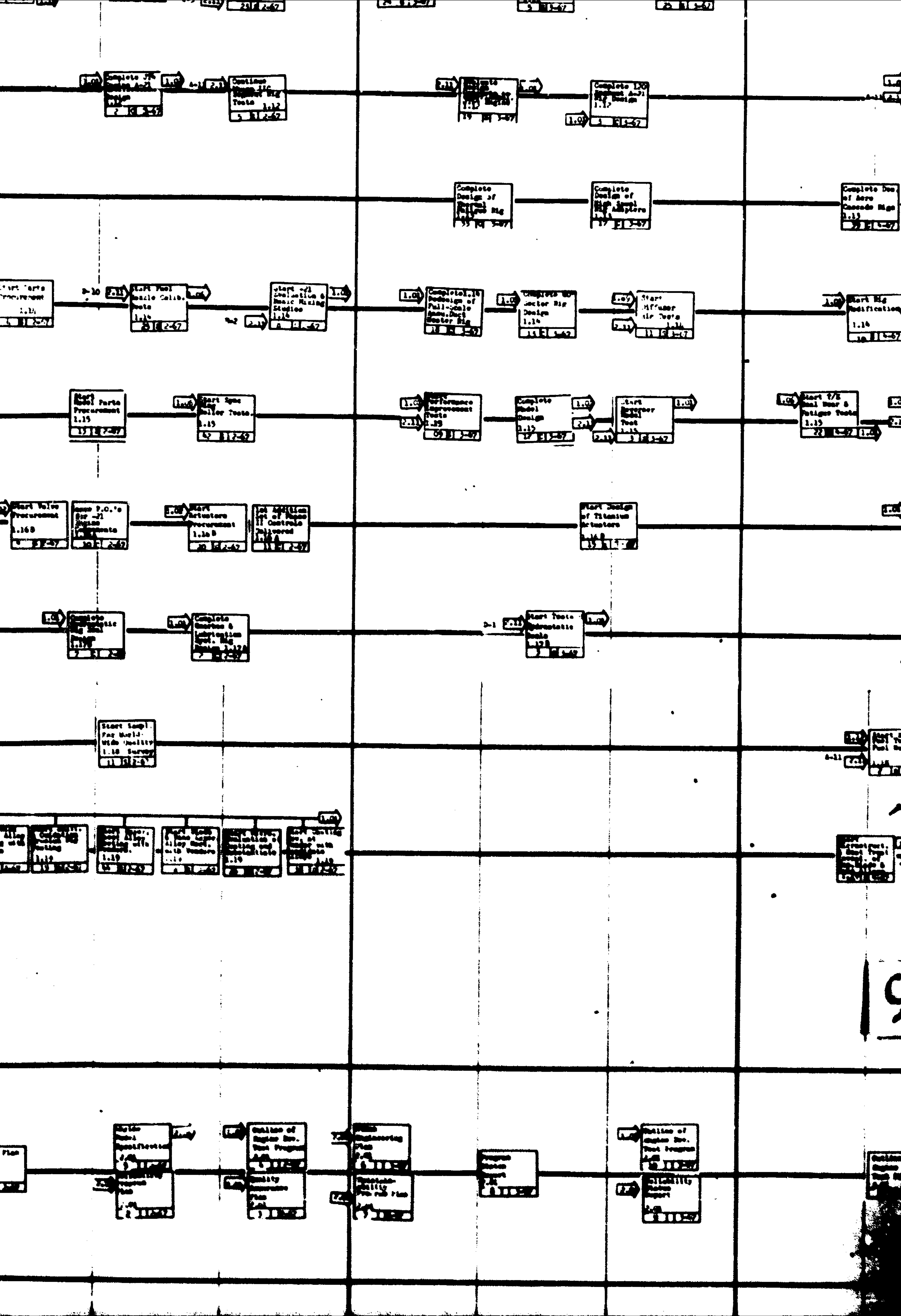
AUG
SEP
OCT
Start Calibration Tests 1.04
Start Hot Environment And Vibration Tests 1.04
Complete A-5 Test Equip. Installation 1.05
Complete D-12 Test Equip. Installation 1.05
Complete Build of 1st Refurbished Engine 1.02
Start 6e Development Engine Tests 1.06
Start S/L Endur. Testing of Engs. 1.06
Start Tests of 1st Refurbished Engine 1.06

16

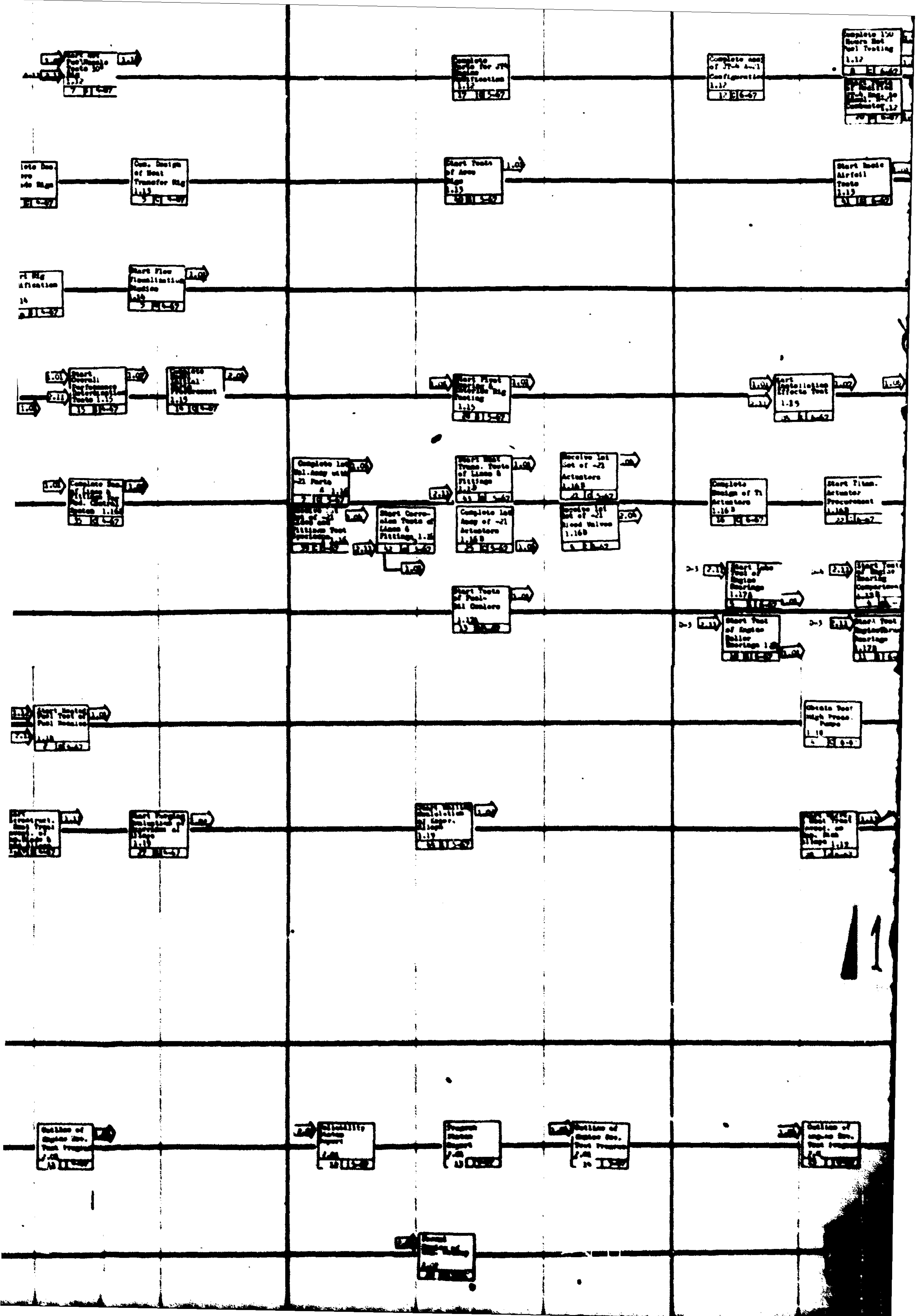

OCT
NOV
Complete Mounting Hardware Design 1.01
Complete Build of 1st Refurbished Engine 1.02
Complete PFRT Procurement for 2nd Refurbished Engine 1.02
Complete D-12 Test Equip. Installation 1.05
Complete Ignition Sys Environ. Bench 2.11
Complete A-5 Stand 2.11
Complete D-7 Test Equip. Installation 1.05
Complete Electronic Test Equip. Installation 1.05
Complete D-10 Test Equip. Installation 1.05
Complete D-11 Test Equip. Installation 1.05
Complete D-14 Test Equip. Installation 1.05
Complete Test Equip. Installation 1.05
Complete D-16 Test Equip. Installation 1.05
Complete C-12 Stand 2.11
Start Hyd. Pump Test Bench 1.05
Complete C-7 Test Equip. Installation 1.05
Start Tests of 1st Refurbished Engine 1.06
Continue Perform. Tests of Engines 1.06
Start Engine Tests of Turbine 1.06
Start Inlet Distortion Tests 1.06
Perform Anal. of Inlet Distor. Tests 1.07
Start Engine Test with Distortion Screens 1.06
Start Tests of 2nd Compressor Rig


NOV
DEC
Complete Mounting Hardware Design 1.01
Establish Ground Test Engine Parts List 1.01
Complete Procurement for 2nd Refurbished Engine 1.02
Complete Build of 2nd Refurbished Engine 1.02
Complete D-7 Test Equip. Installation 1.05
Complete Electronic Test Equip. Installation 1.05
Complete D-1 Test Equip. Installation 1.05
Complete D-11 Test Equip. Installation 1.05
Complete D-2 Test Equip. Installation 1.05
Complete D-16 Test Equip. Installation 1.05
Start Hyd. Pump Test Bench 1.05
Complete C-7 Test Equip. Installation 1.05
Complete Electronic Control Bench 2.11
Complete D-10 Stand 2.11
Complete Test Equip. for D-7 Stand 1.05
Start Fuel Control Test Bench 1.05
Start Engine Tests of Turbine 1.06
Start Inlet Distortion Tests 1.06
Start Tests of 2nd Refurbished Engine 1.06
Perform Inlet Distortion Tests 1.07

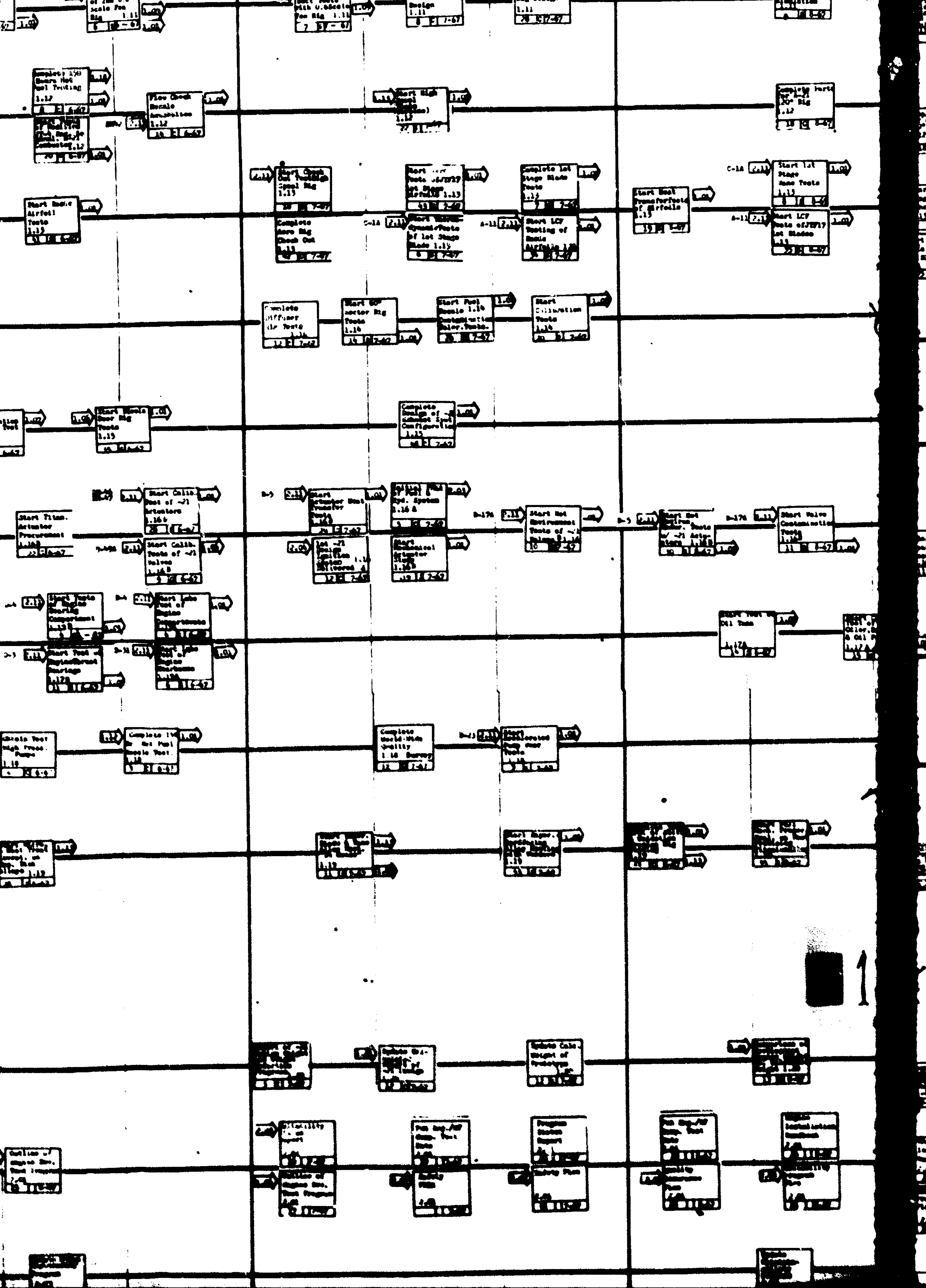

PRIMARY COMBUSTOR
1.12
TURBINE
1.13
AUGMENTOR
1.14
EXHAUST SYSTEM
1.15
CONTROLS AND ACCESSORIES
1.16
LUBRICANTS, LUBRICATION SYSTEM
BEARINGS, SEAL, AND GEARS
1.17
FUELS
1.18
MANUFACTURING TECHNIQUES
AND MATERIALS
1.19
START
PHASE III
1-1-67
WEIGHT CONTROL AND STATUS
1.20
COORDINATION
2.01
MAINTAINABILITY
HUMAN ENGINEERING
2.02



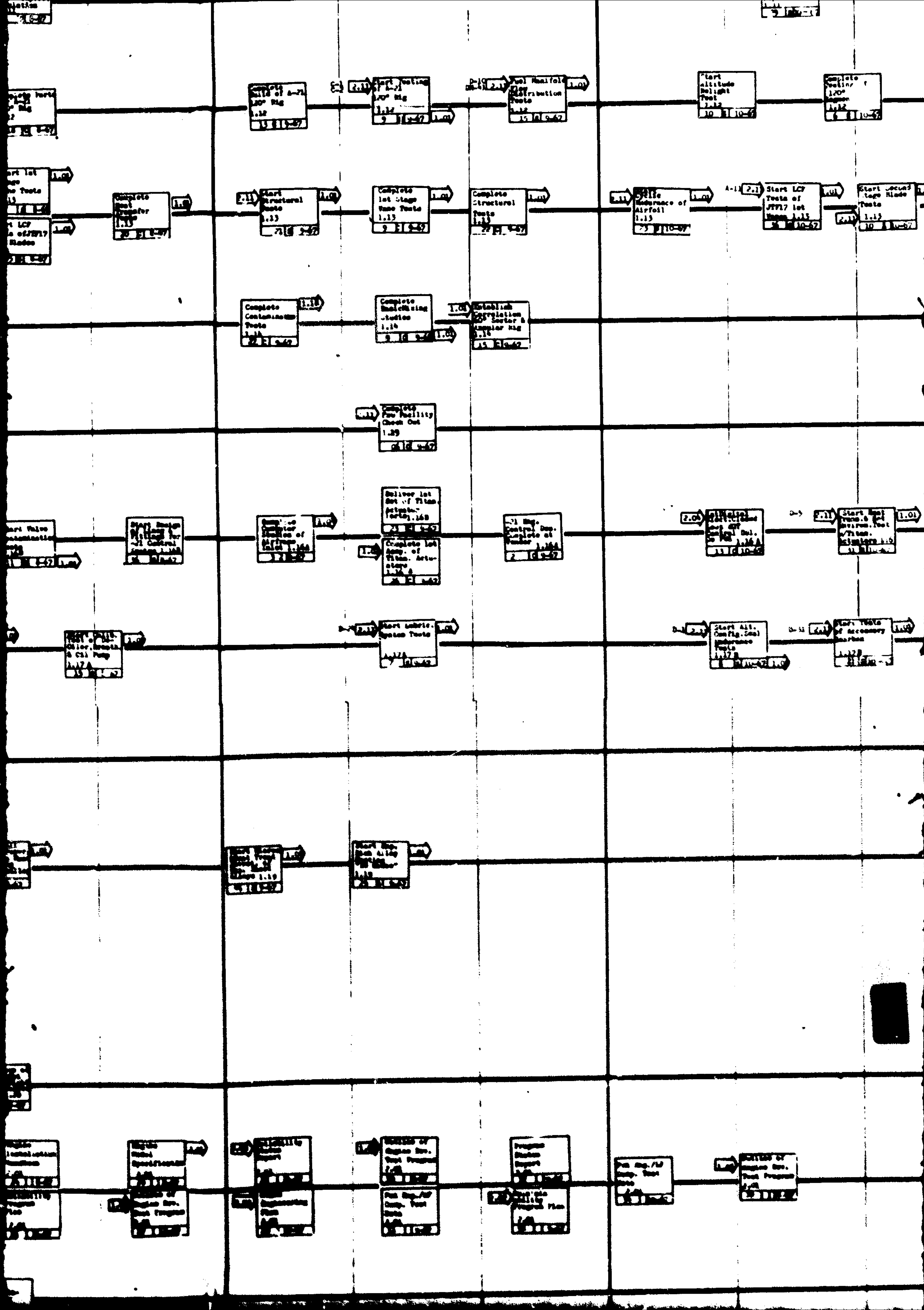
Complete Design of Aero Cascade Rigs 1.15
Start Rig Modification 1.14
Start Fuel Nozzle Calib. Tests 1.14
Start Diffuser Air Tests 1.14
Start Model Parts Procurement 1.15
Start Sync Ring Roller Tests 1.15
Complete Model Design 1.15
Start Valve Procurement 1.16 B
Start Actuators Procurement 1.16 B
Start Design of Titanium Actuators 1.16 B
Complete Gearbox & Lubrication Test Rig Design 1.17 A
Start Tests Hydrostatic Seals 1.17 B
Start Sampl. Fan Weld-Wide Quality 1.18 Survey
Outline of Engine Dev. Test Program
Quality Assurance Plan
Program Status Report
Reliability Status Report



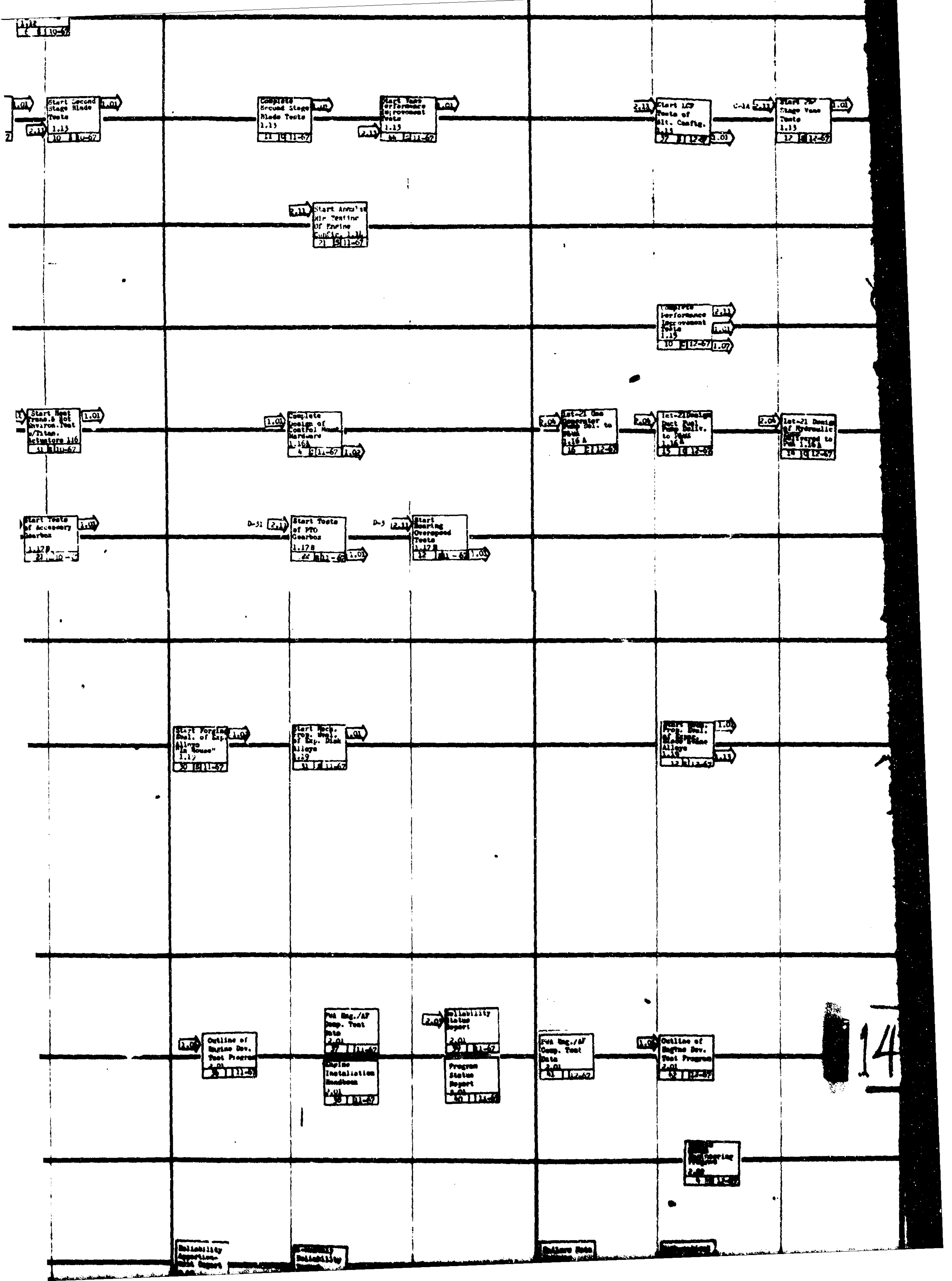
Start Basic Airfoil Tests 1.13
Complete Design of Ti Actuators 1.16
Start Titan. Actuator Procurement
Receive 1st Set of -21 Actuators
Obtain Test High Press. Pumps 1.18



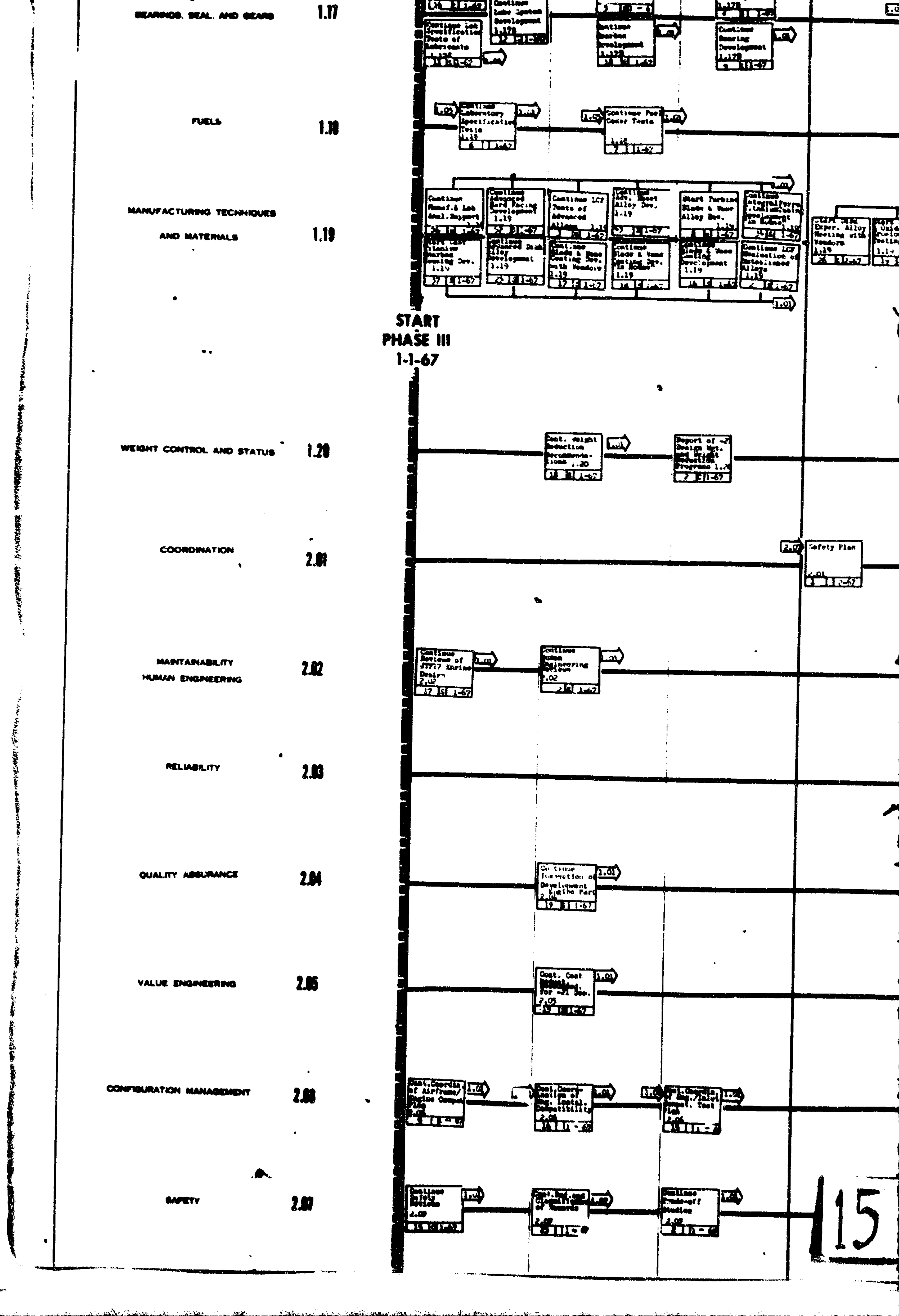
Start Basic Airfoil Tests 1.13
Flow Check Nozzle
Complete Aero Rig Check Out 1.13
Start Fuel Nozzle 1.14
Start Calibration Tests 1.14
Start Titan. Actuator Procurement
Start Calib. Test of -21 Actuators
Start Calib. Tests of -21 Valves
Start Hot Environment Tests
Start Valve Contamination Tests
Update Calc. Weight of Prototype
Program Status Report
Safety Plan



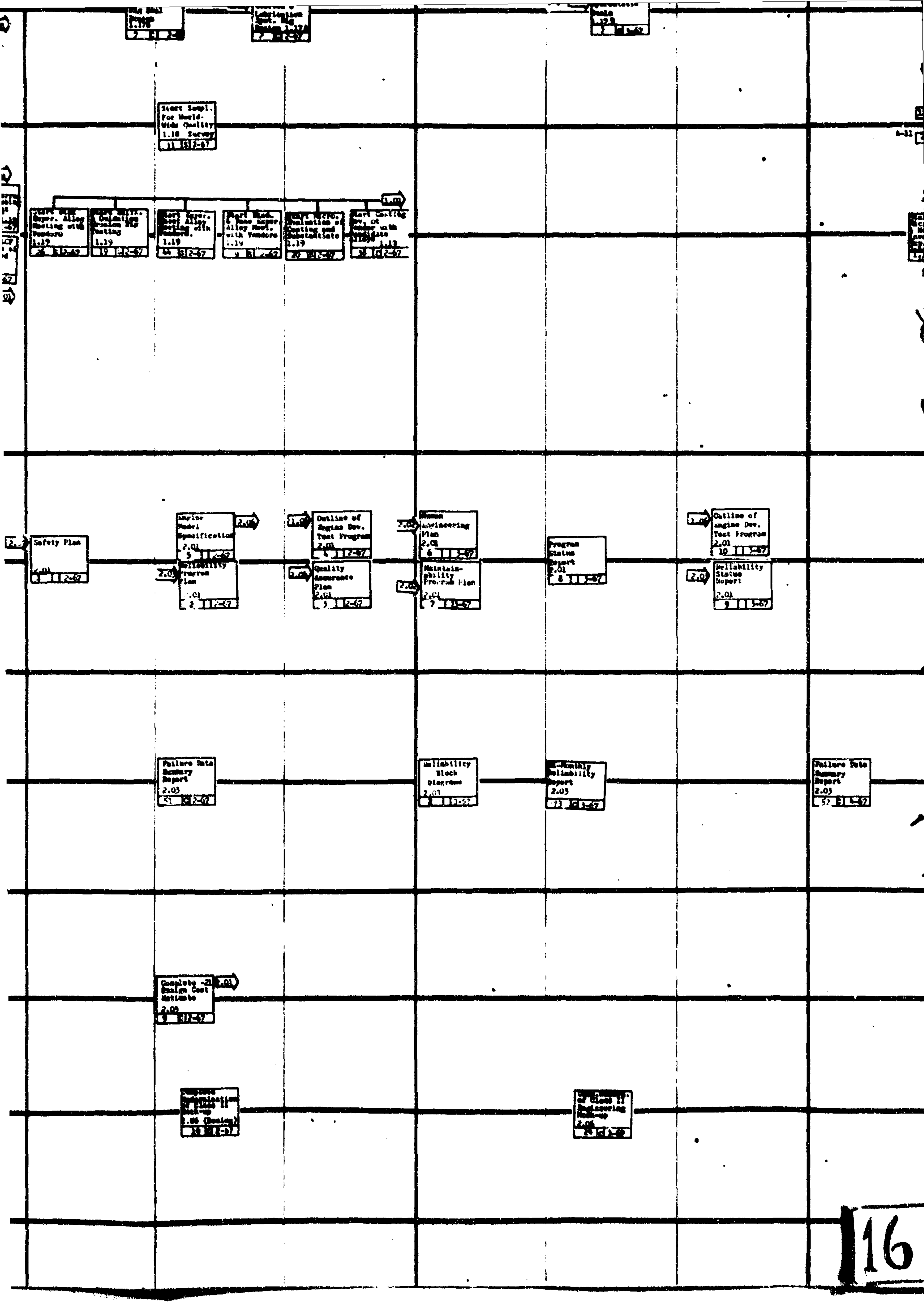
Complete Build of A-21 120° Rig 1.12
Fuel Manifold Flow Distribution Tests 1.12
Start Altitude Relight Test 1.12
Complete Heat Transfer Tests 1.13
Start Structural Tests 1.13
Complete 1st Stage Vane Tests 1.13
Complete Structural Tests 1.13
Start LCF Tests of JTF17 1st Vanes 1.13
Complete Contamination Tests 1.14
Complete Scale Mixing Studies 1.14
Establish Correlation 120° Sector & Annular Rig 1.14
Complete Fan Facility Check Out 1.29
Deliver 1st Set of Titan. Actuator Parts 1.16B
Complete 1st Assy. of Titan. Actuators 1.16A
Start Lubric. System Tests 1.17A
Start Alt. Config. Seal Endurance Tests 1.17B
Start Tests of Accessory Gearbox
Program Status Report
Fan Eng./AF Comp. Test Data
Reliability Program Plan
Engineering Plan



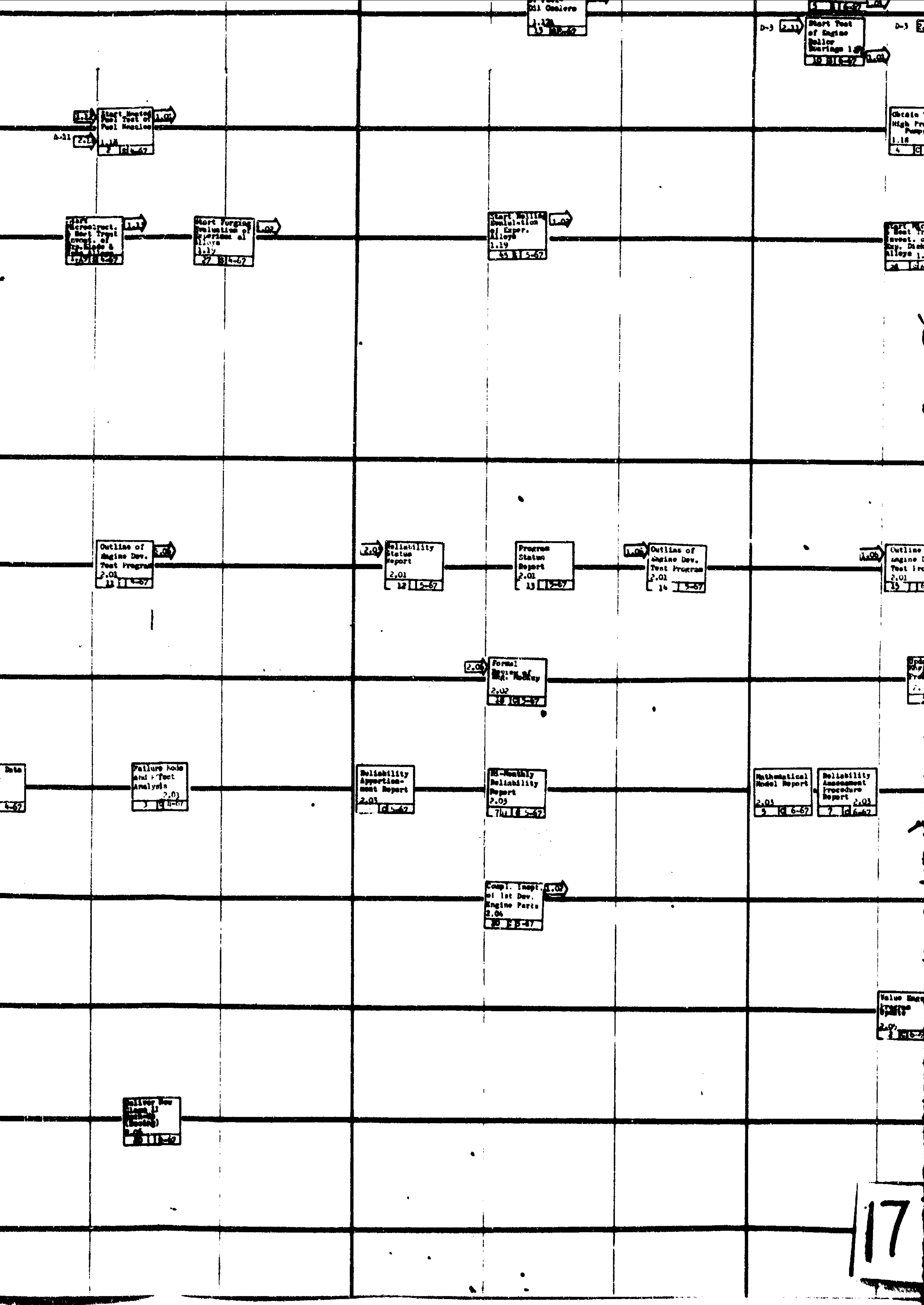
Start Second Stage Blade Tests 1.13
Complete Second Stage Blade Tests 1.13
Start Vane Performance Improvement Tests 1.13
Start LCP Tests of Alt. Config.
Start Stage Vane Tests 1.13
Start Annular Air Testing of Engine Config. 1.14
Complete Performance Improvement Tests 1.15
Complete Design of Control Mount Hardware 1.16A
Start Tests of Accessory Gearbox 1.12B
Start Tests of PTO Gearbox 1.17B
Start Bearing Overspeed Tests 1.17B
Start Forging Eval. of Exp. Alloys "In House" 1.19
Start Mech. Prop. Eval. of Exp. Disk Alloys 1.19
Outline of Engine Dev. Test Program 2.01
FAA Eng./AF Comp. Test Data 2.01
Engine Installation Handbook 2.01
Reliability Status Report
Program Status Report
FAA Eng./AF Comp. Test Data 2.01
Outline of Engine Dev. Test Program 2.01
Reliability
Reliability
14



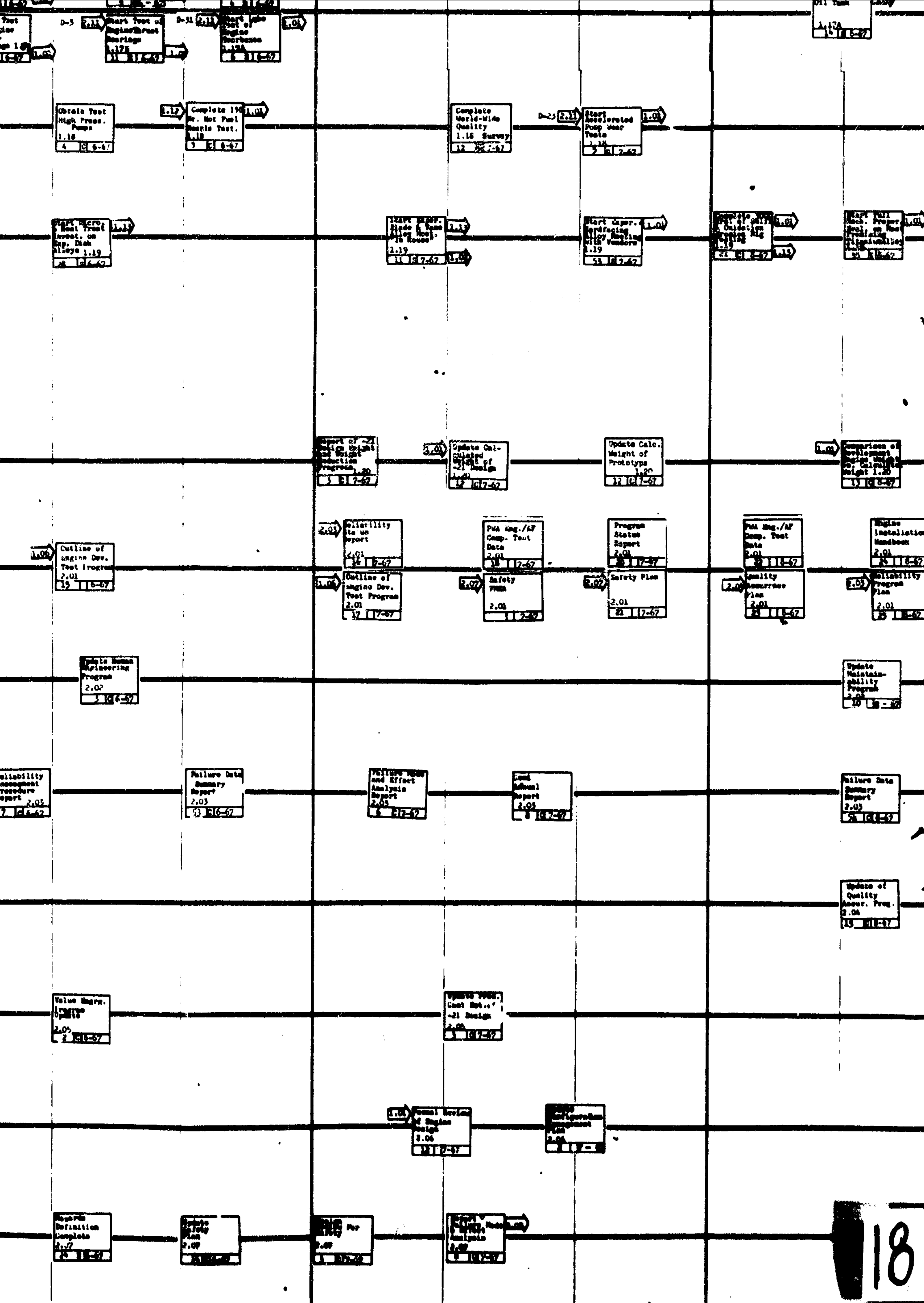
BEARINGS, SEAL AND GEARS
1.17
FUELS
1.18
MANUFACTURING TECHNIQUES
AND MATERIALS
1.19
START
PHASE III
1-1-67
WEIGHT CONTROL AND STATUS
1.20
COORDINATION
2.01
MAINTAINABILITY
HUMAN ENGINEERING
2.02
RELIABILITY
2.03
QUALITY ASSURANCE
2.04
VALUE ENGINEERING
2.05
CONFIGURATION MANAGEMENT
2.06
SAFETY
2.07
Safety Plan
15

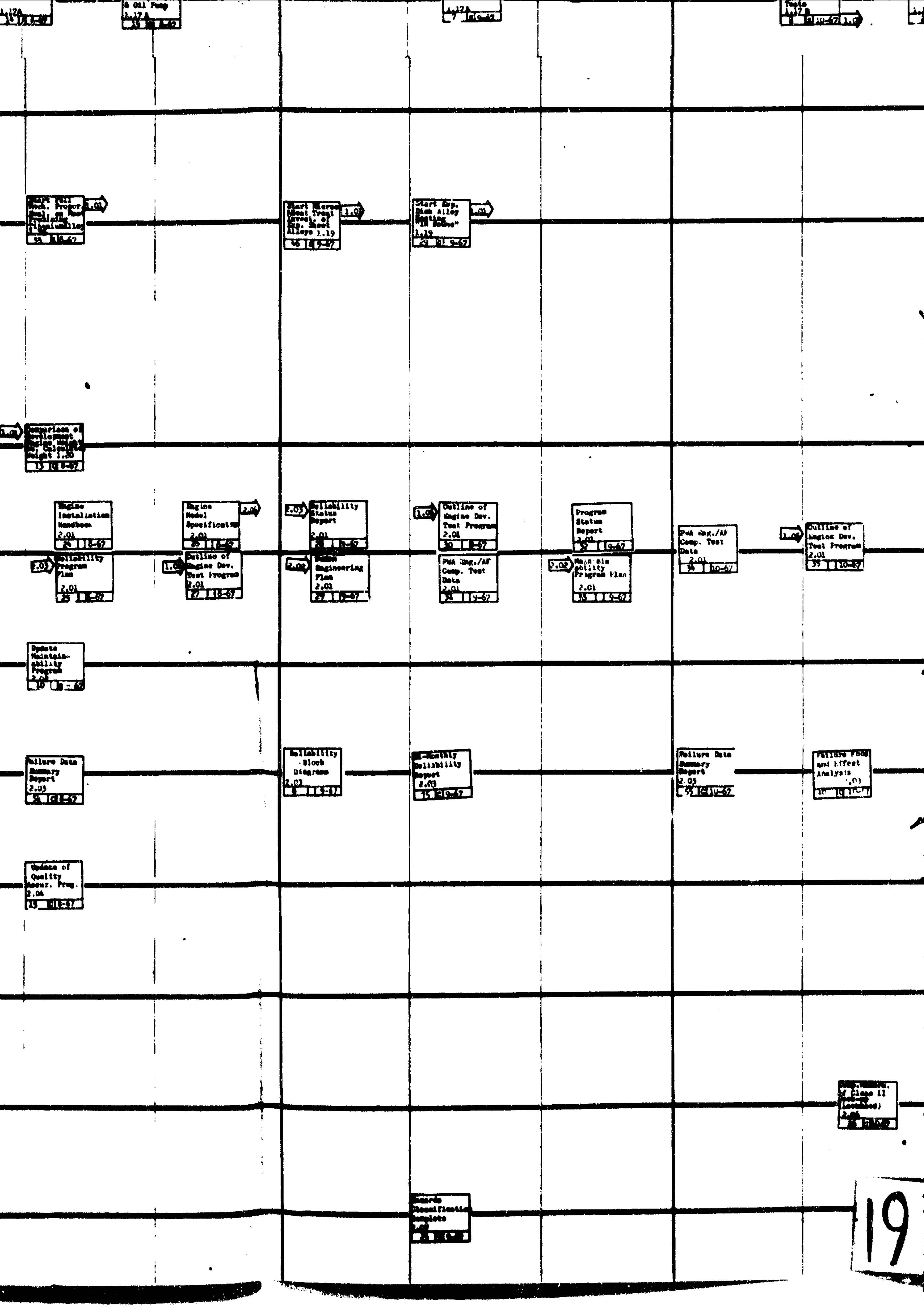


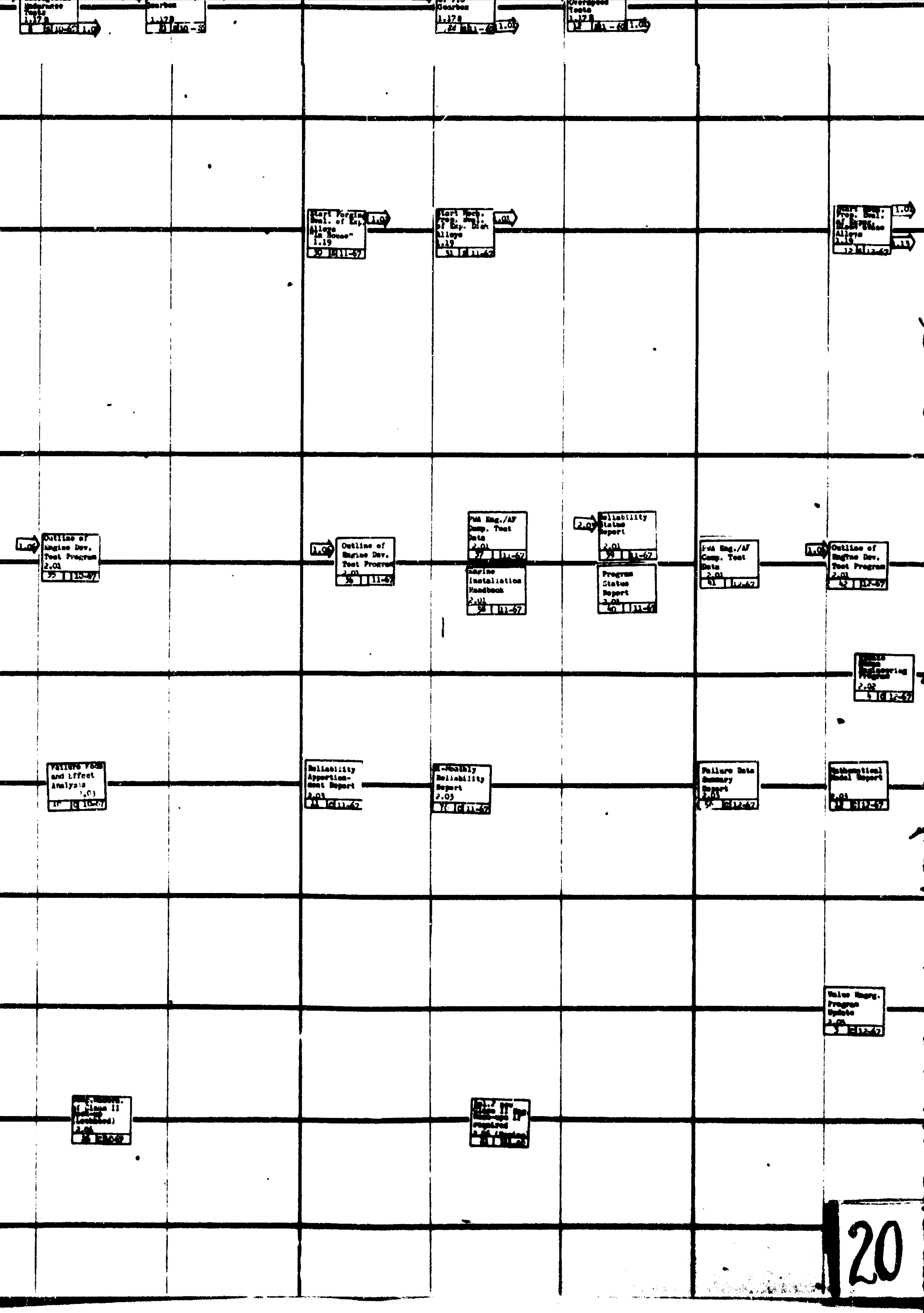
Start Sampl. For World-Wide Quality 1.18 Survey
Safety Plan
Engine Model Specification 2.01
Reliability Program Plan
Outline of Engine Dev. Test Program 2.01
Quality Assurance Plan 2.01
Human Engineering Plan 2.01
Maintainability Program Plan 2.01
Program Status Report 2.01
Outline of Engine Dev. Test Program 2.01
Reliability Status Report 2.01
Failure Data Summary Report 2.03
Reliability Block Diagrams
Bi-Monthly Reliability Report 2.03
Failure Data Summary Report 2.03
Complete -21 Design Cost Estimate 2.05
Engineering Mock-up

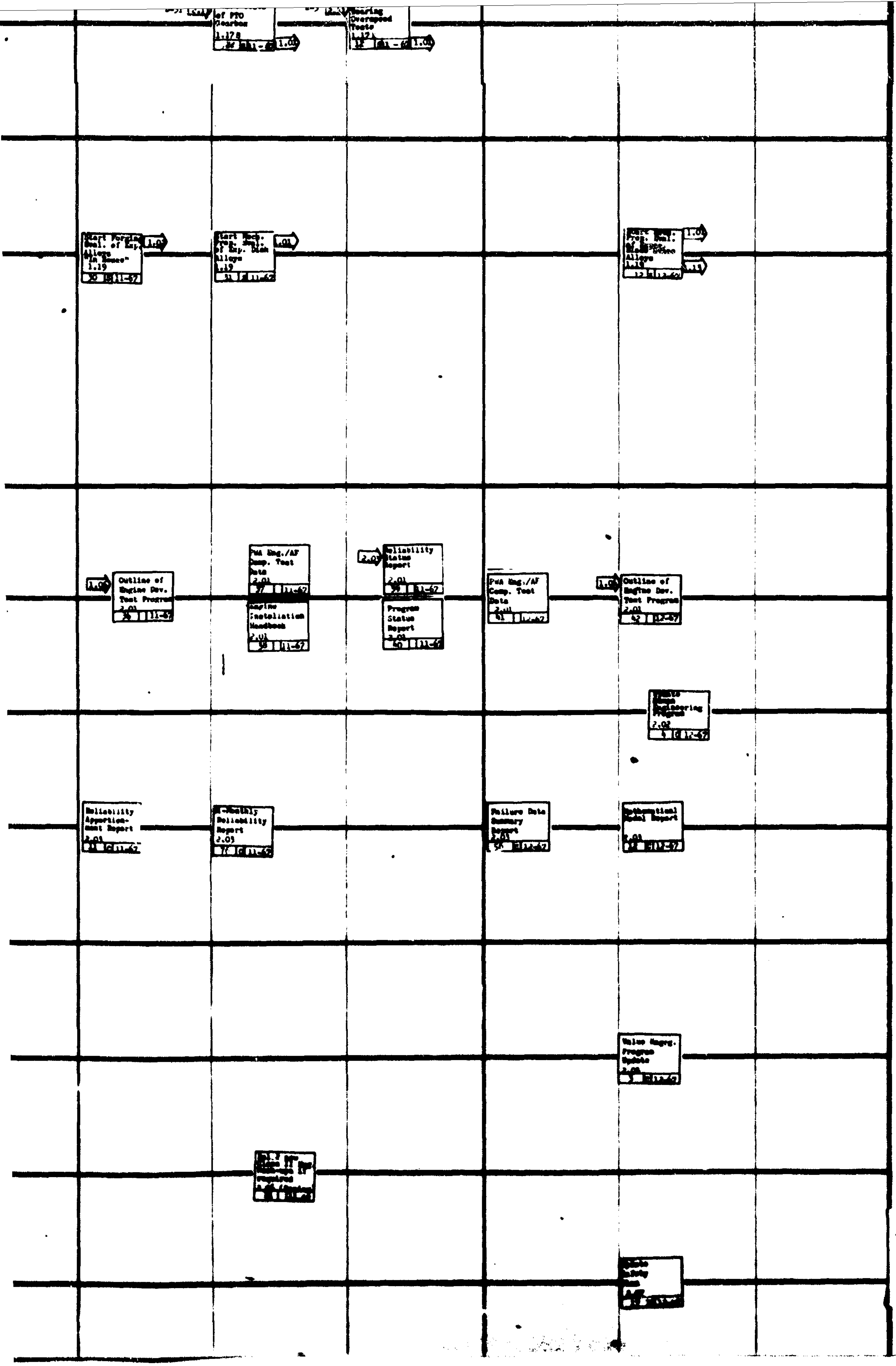


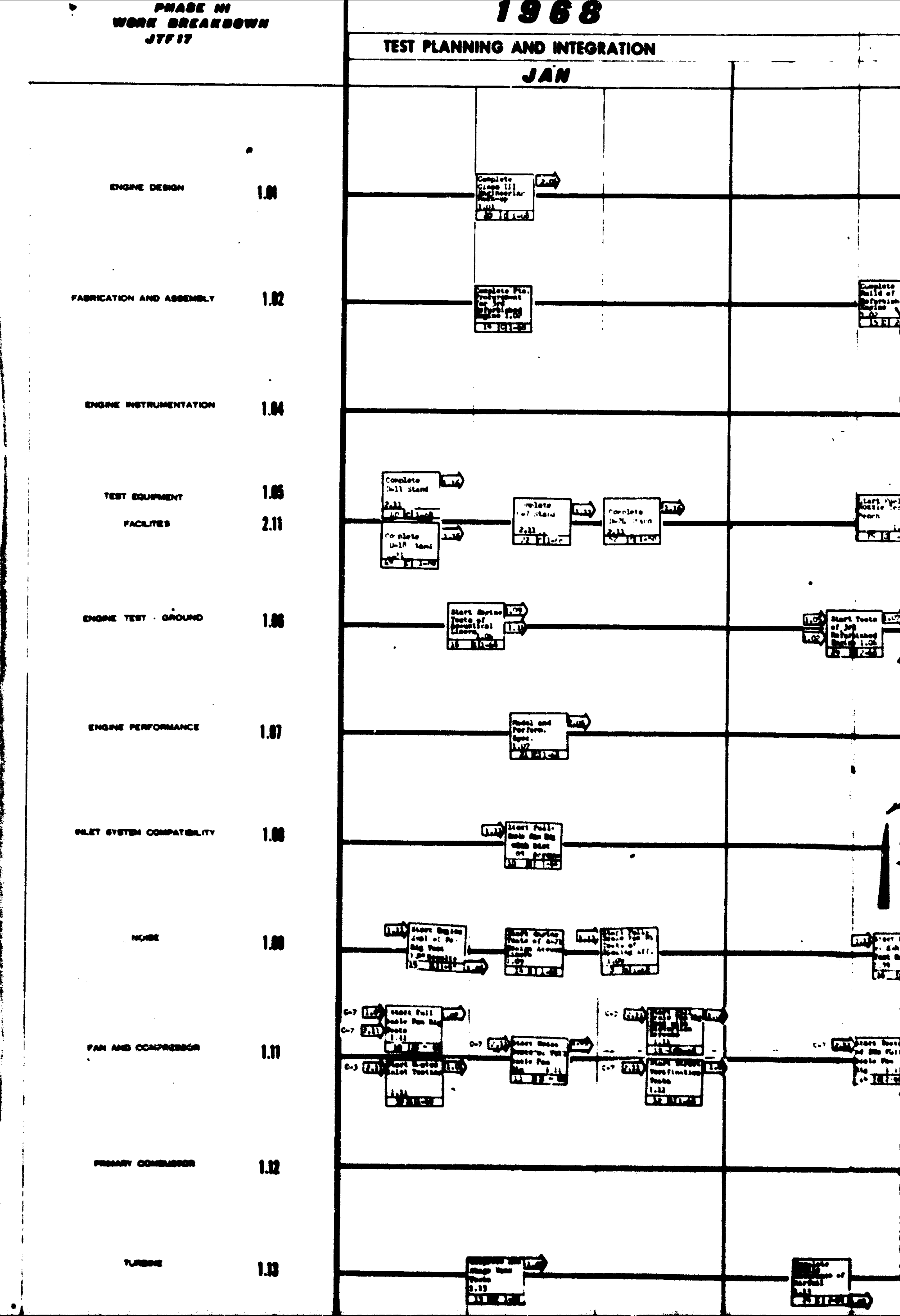
Oil Coolers
Start Test of Engine Roller Bearings
Start Heated Fuel Test of Fuel Nozzles
Obtain High Pressure Pumps
Start Forging Evaluation of Experimental Alloys
Start Rolling Evaluation of Exper. Alloys
Outline of Engine Dev. Test Program
Reliability Status Report
Program Status Report
Outline of Engine Dev. Test Program
Formal Review of Eng. Mockup
Failure Mode and Effect Analysis
Reliability Apportionment Report
Bi-Monthly Reliability Report
Mathematical Model Report
Reliability Assessment Procedure Report
Compl. Inspt. of 1st Dev. Engine Parts
Value Engineering Program

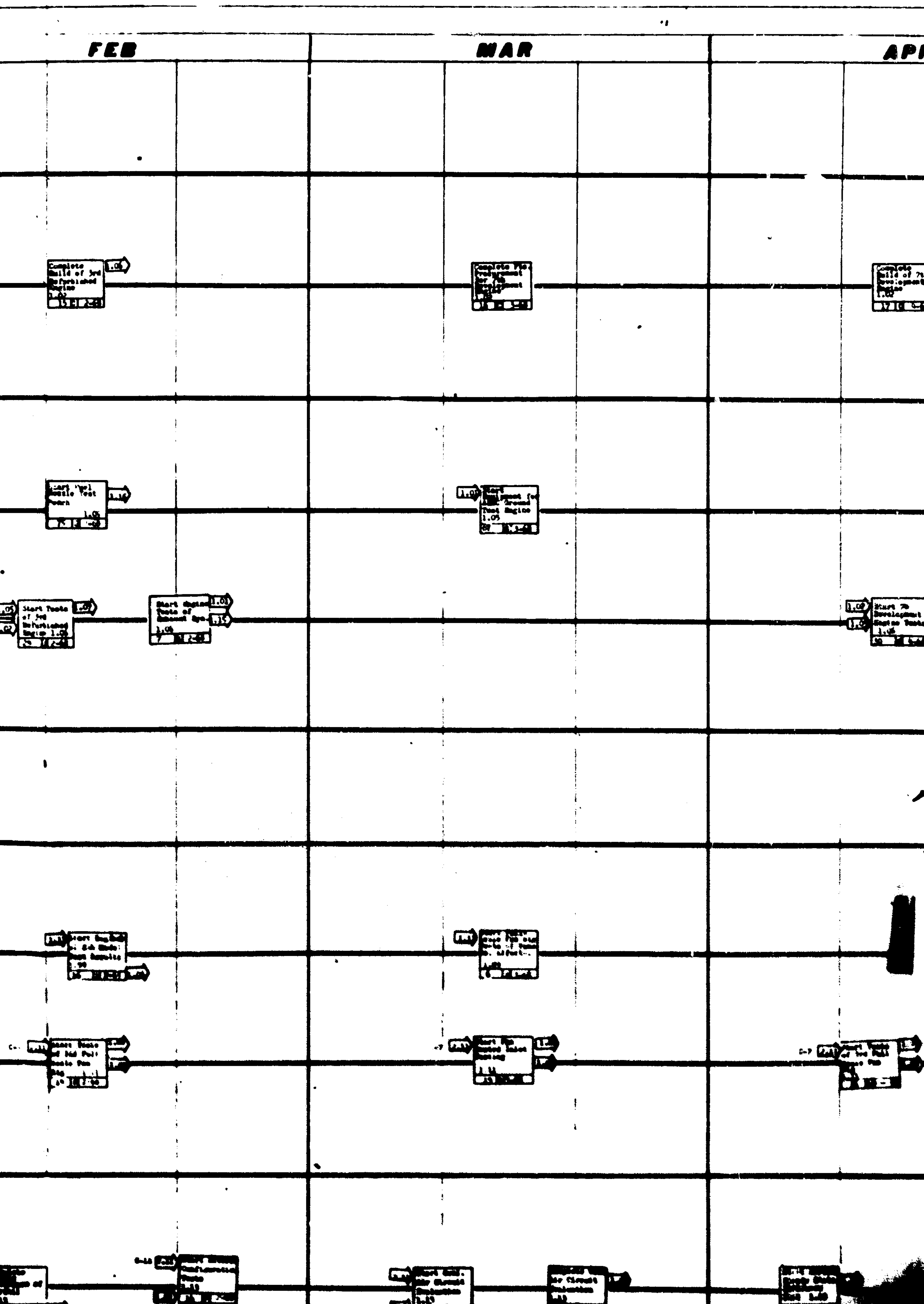

Obtain Test High Press. Pumps 1.18
Complete World-Wide Quality 1.18 Survey
Start Accelerated Pump Wear Tests
Start Exper. Hardfacing Alloy Reading with Vendors 1.19
Update Calc. Weight of Prototype 1.20
Update Calculated Weight of -21 Design
Reliability Status Report
PWA Eng./AF Comp. Test Data 2.01
Program Status Report 2.01
Engine Installation Handbook 2.01
Outline of Engine Dev. Test Program 2.01
Safety FMEA 2.01
Safety Plan 2.01
Quality Assurance Plan 2.01
Reliability Program Plan 2.01
Update Human Engineering Program 2.02
Update Maintainability Program
Failure Data Summary Report 2.03
Failure Mode and Effect Analysis Report 2.03
Update of Quality Assur. Prog. 2.04
Value Engrg. Program Update 2.05
Formal Review of Engine Design 2.06
Update Safety Plan 2.07


& Oil Pump
1.17A
Start Exp. Disk Alloy Testing "In House" 1.19
Comparison of Development Engine Weight to Calculated Weight 1.20
Engine Installation Handbook 2.01
Engine Model Specification 2.01
Reliability Status Report 2.01
Outline of Engine Dev. Test Program 2.01
Program Status Report 2.01
PWA Eng./AF Comp. Test Data 2.01
Reliability Program Plan 2.01
Outline of Engine Dev. Test Program 2.01
Human Engineering Plan 2.01
PWA Eng./AF Comp. Test Data 2.01
Maintainability Program Plan 2.01
Outline of Engine Dev. Test Program 2.01
Update Maintainability Program
Failure Data Summary Report 2.03
Reliability Block Diagrams 2.03
Bi-Monthly Reliability Report 2.03
Failure Data Summary Report 2.03
Failure Mode and Effect Analysis
Update of Quality Assur. Prog. 2.04
Standards Classification Complete

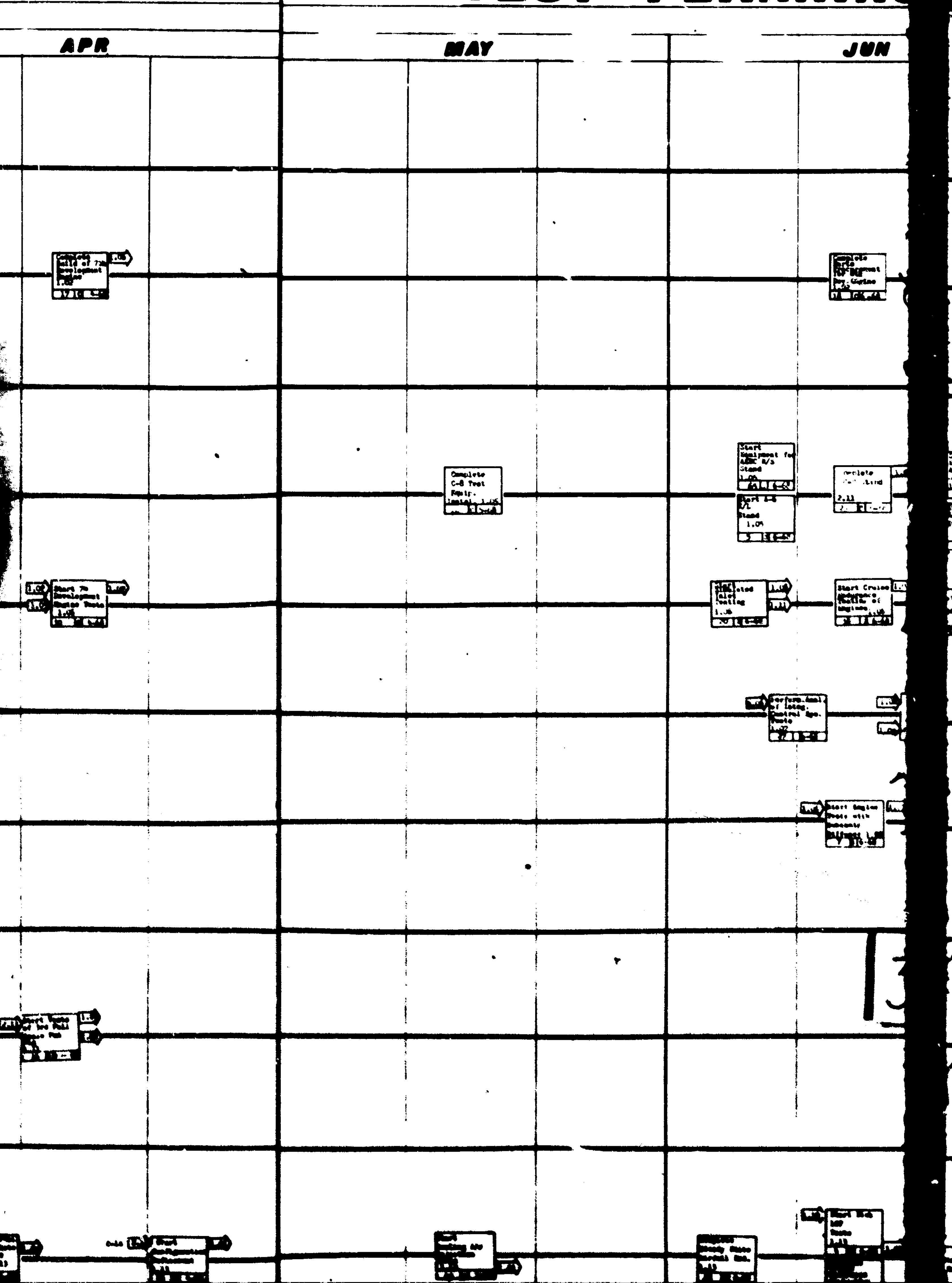

Outline of
Engine Dev.
Test Program
2.01
Outline of
Engine Dev.
Test Program
2.01
PWA Eng./AF
Comp. Test
Data
2.01
Engine
Installation
Handbook
2.01
Reliability
Status
Report
2.01
Program
Status
Report
PWA Eng./AF
Comp. Test
Data
2.01
Outline of
Engine Dev.
Test Program
2.01
Failure Mode
and Effect
Analysis
Reliability
Apportionment Report
2.03
Bi-Monthly
Reliability
Report
2.03
Failure Data
Summary
Report
2.03
Mathematical
Model Report
Value Engrg.
Program
Update
Start Forging
Eval. of Exp.
Alloys
"In House"
1.19
Start Mech.
Prop. Eval.
of Exp. Disk
Alloys
1.19

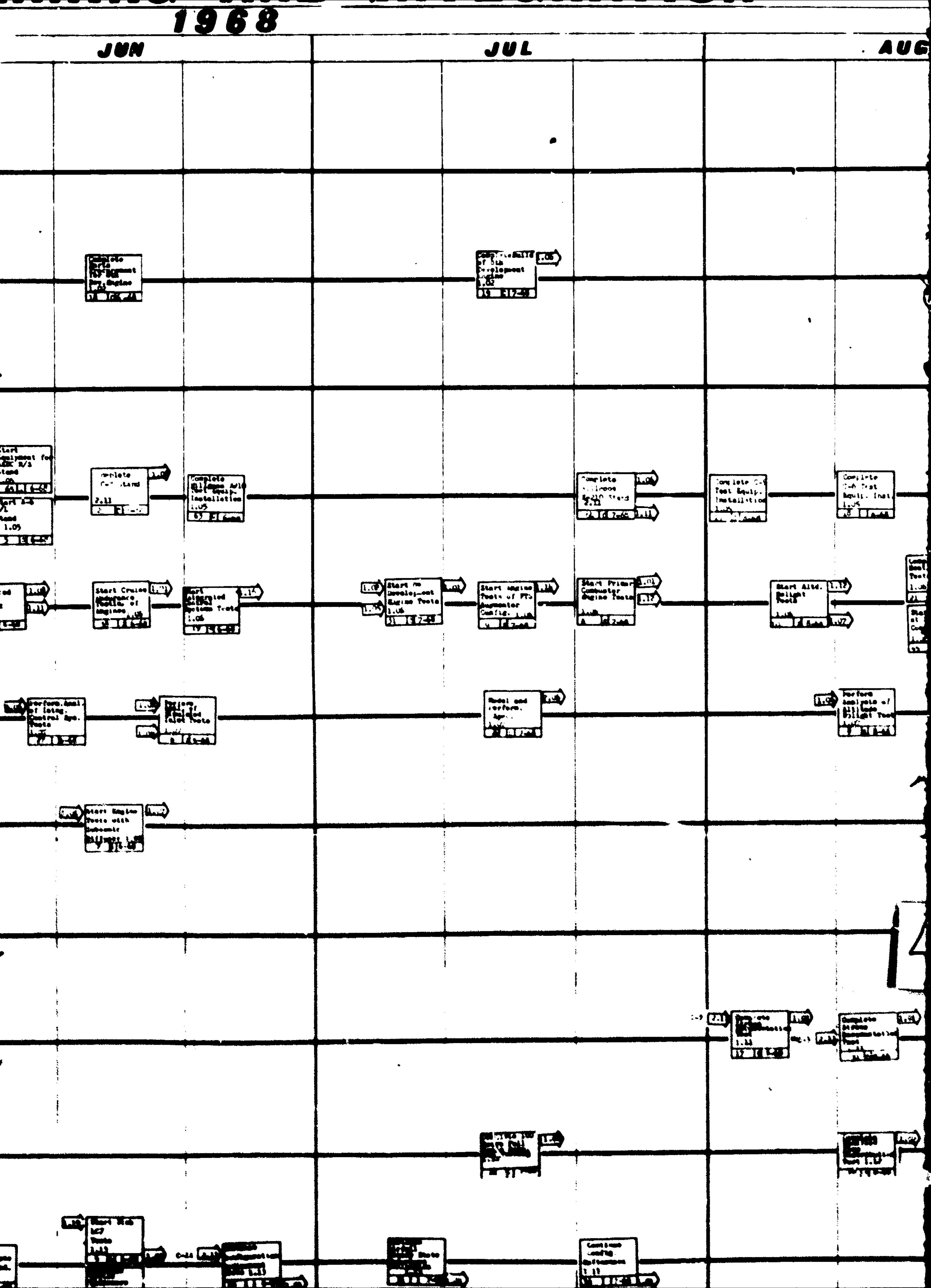

of PTO Gearbox 1.17a
Overspeed Tests 1.17
1.01
Alloys 1.19
Alloys 1.19
1.01
Outline of Engine Dev. Test Program 2.01
1.0
P&A Eng./AF Comp. Test Data 2.01
Engine Installation Handbook 2.01
2.03
Reliability Status Report 2.01
Program Status Report
P&A Eng./AF Comp. Test Data 2.01
Outline of Engine Dev. Test Program 2.01
Engineering Program 2.02
Reliability Apportion-ment Report
Reliability Report 2.03
Failure Data Summary Report
Value Engrg. Program Update
11-67
12-67


PHASE III
WORK BREAKDOWN
JTF17
1968
TEST PLANNING AND INTEGRATION
JAN
ENGINE DESIGN
1.01
FABRICATION AND ASSEMBLY
1.02
ENGINE INSTRUMENTATION
1.04
TEST EQUIPMENT
1.05
FACILITIES
2.11
ENGINE TEST - GROUND
1.06
ENGINE PERFORMANCE
1.07
INLET SYSTEM COMPATIBILITY
1.08
NOISE
1.09
FAN AND COMPRESSOR
1.11
PRIMARY COMBUSTOR
1.12
TURBINE
1.13
Complete Stage III Engineering Mock-up
Complete Fin. Procurement for 3rd Refurbished Engine
Complete C-11 Stand
Complete
Start Engine Tests of Operational Liners
Start Tests of 3rd Refurbished Engine
Model and Perform. Spec.

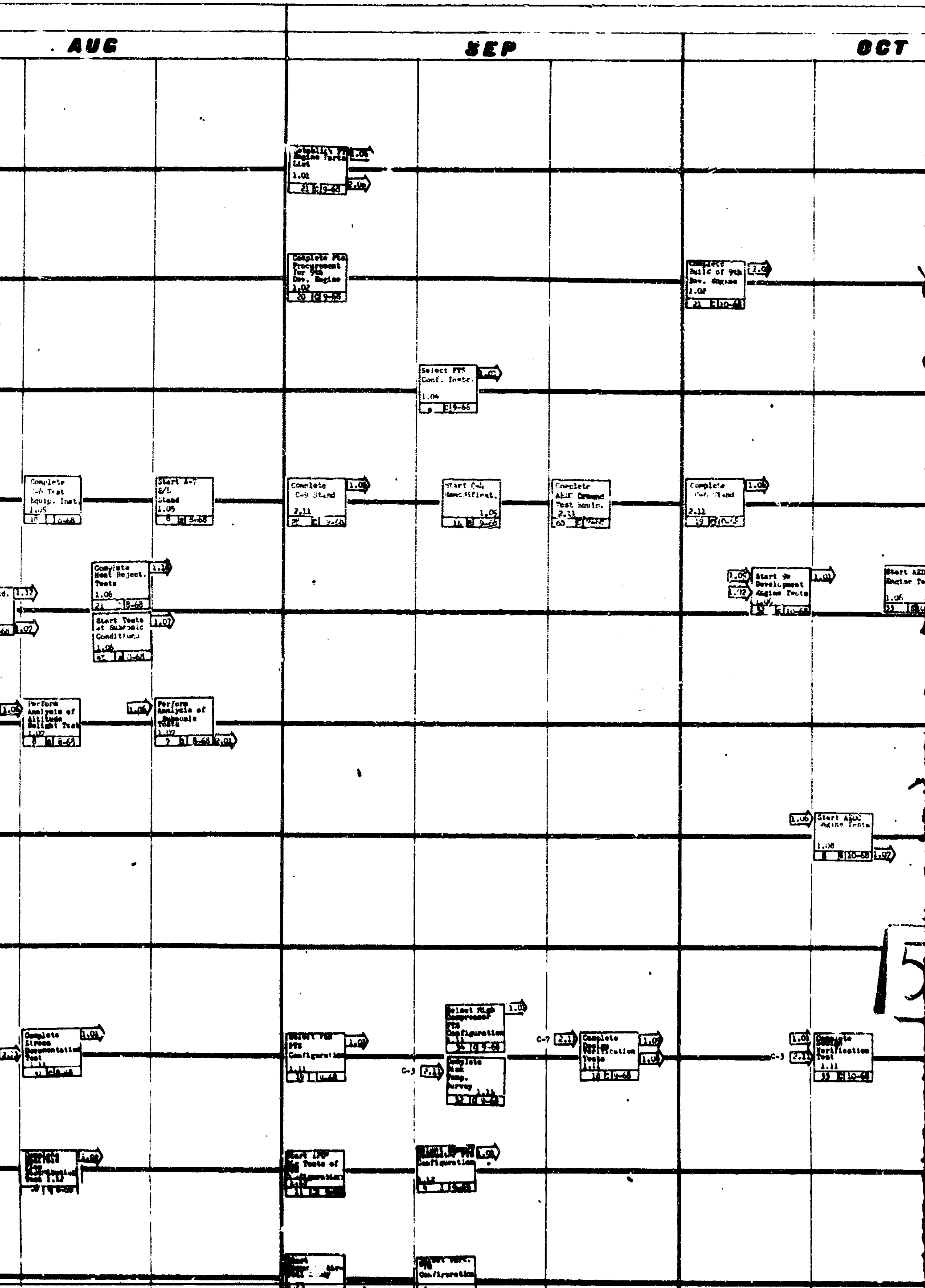

FEB
MAR

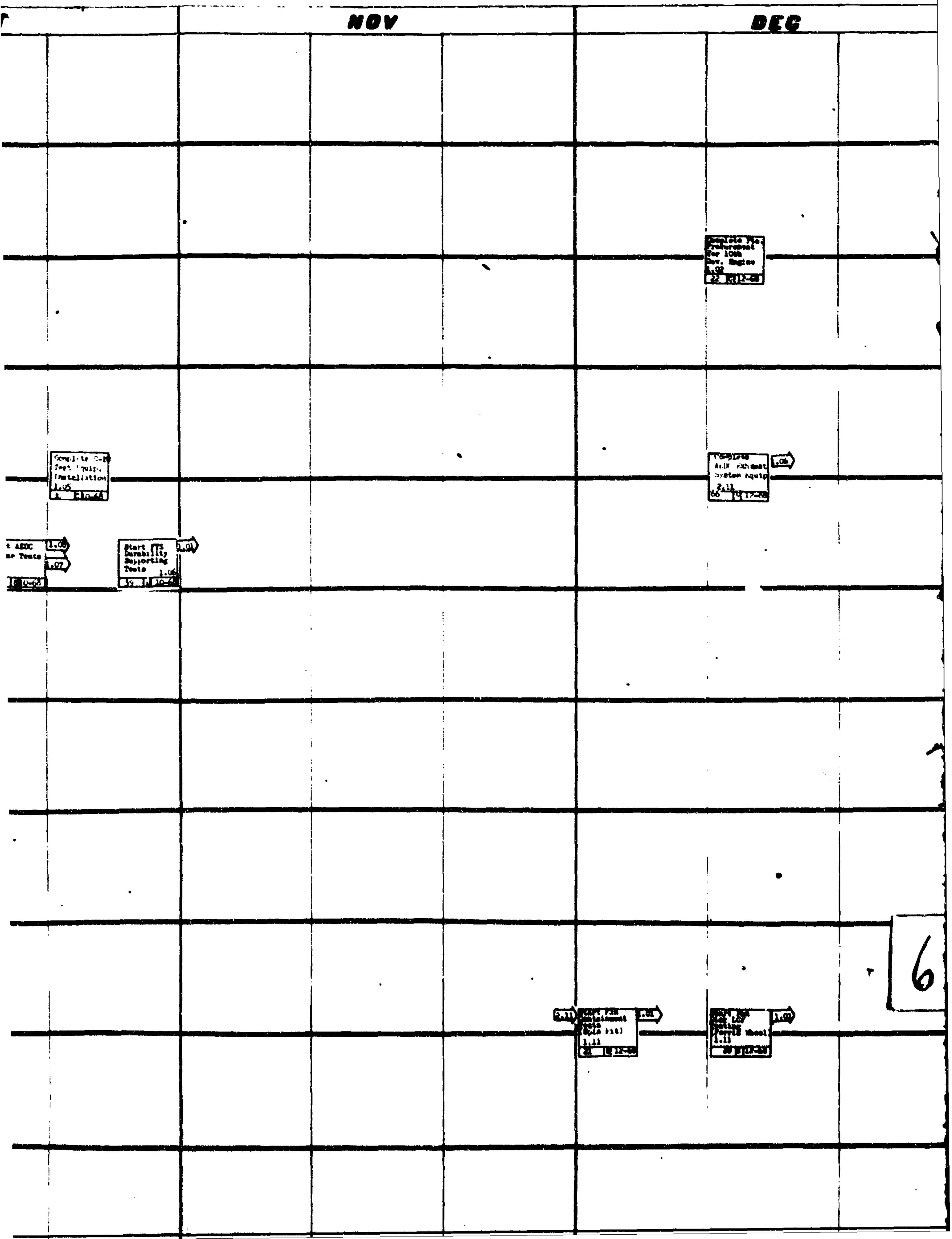
TEST PLANNING

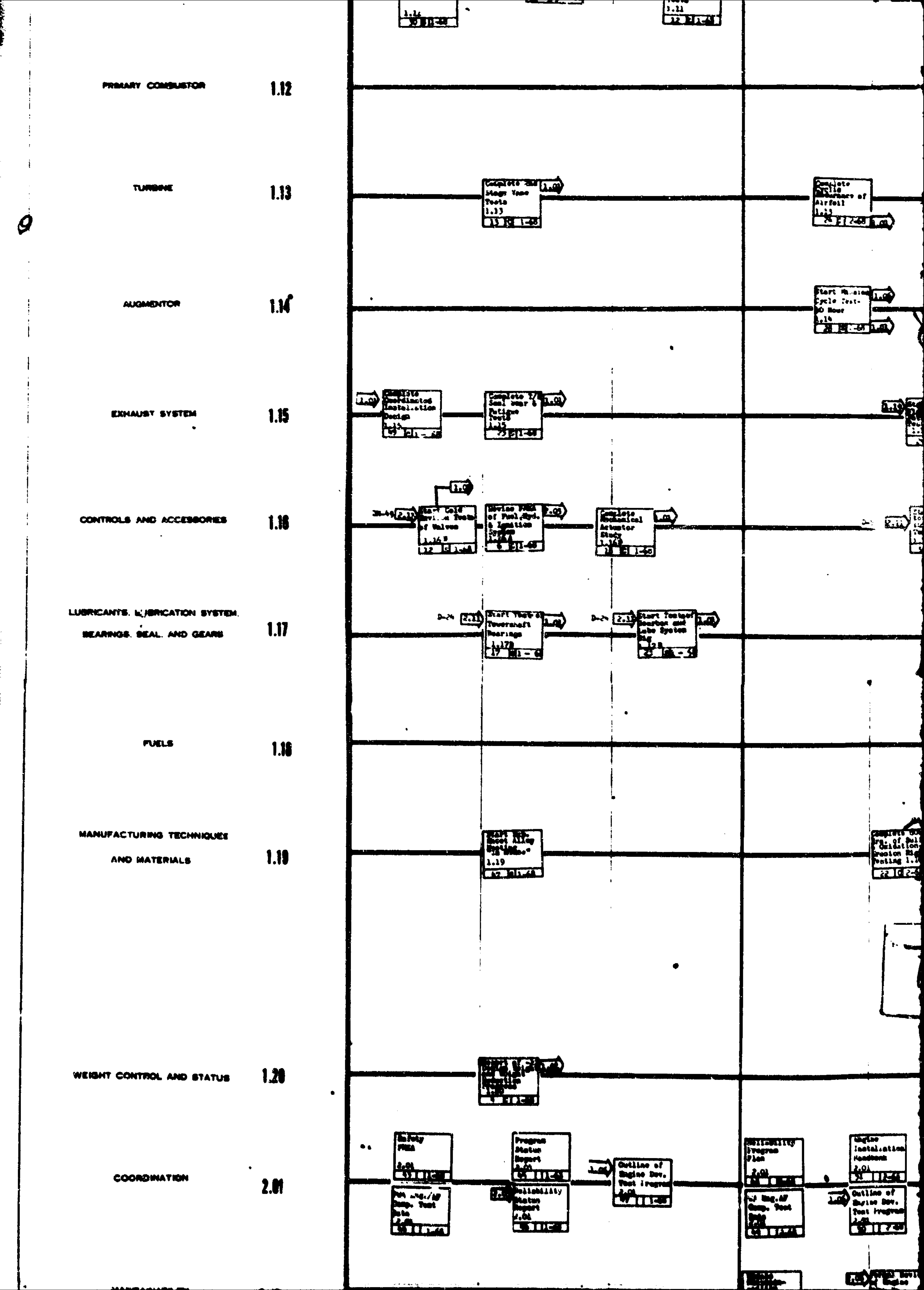




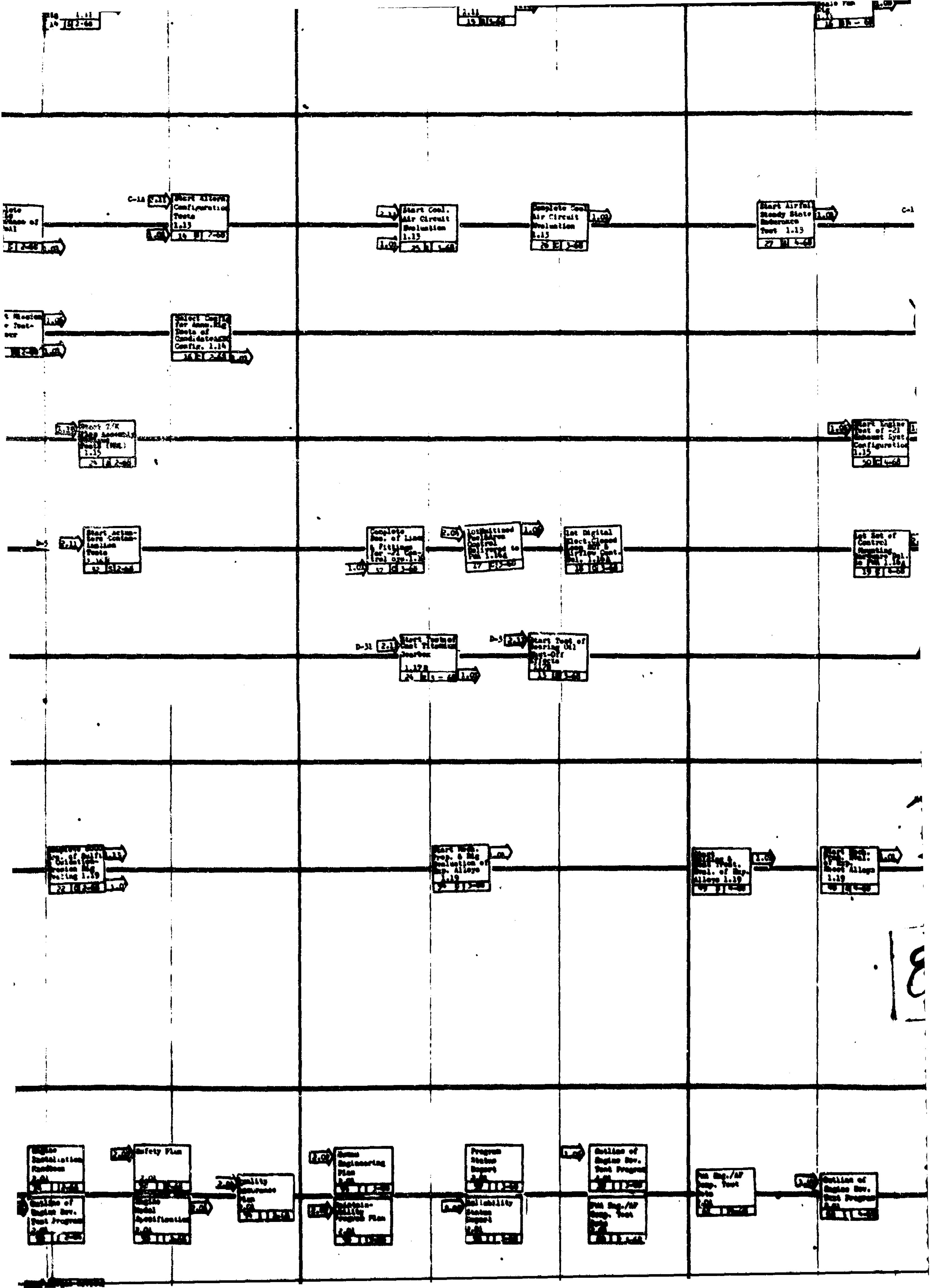
1968
JUN
JUL
AUG
Start Cruise
Start Engine Tests of FTS Augmentor Config.
Start Primary Computer Engine Tests
Start Altd. Relight Tests
Model and Perform
Start Engine Tests with Subsonic


AUG
SEP
OCT
Complete FTS Procurement for 9th Dev. Engine
1.02
Complete Build of 9th Dev. Engine
1.02
Select FTS Conf. Instr.
1.04
Complete C-6 Test Equip. Inst.
1.05
Start A-7 S/L Stand
1.05
Complete C-9 Stand
2.11
Start C-4 Modification
1.05
Complete AEDC Ground Test Equip.
2.11
Complete C-6 Stand
2.11
Complete Heat Reject. Tests
1.06
Start Tests at Subsonic Conditions
1.06
Start 9th Development Engine Tests
Perform Analysis of Altitude Relight Test
1.07
Perform Analysis of Subsonic Tests
Start AEDC Engine Tests
1.08
Complete Stress Documentation Test
1.11
Select High Compressor FTS Configuration
Complete Max Temp. Survey
1.11
Complete Design Verification Tests
1.11
Complete Design Verification Test
1.11

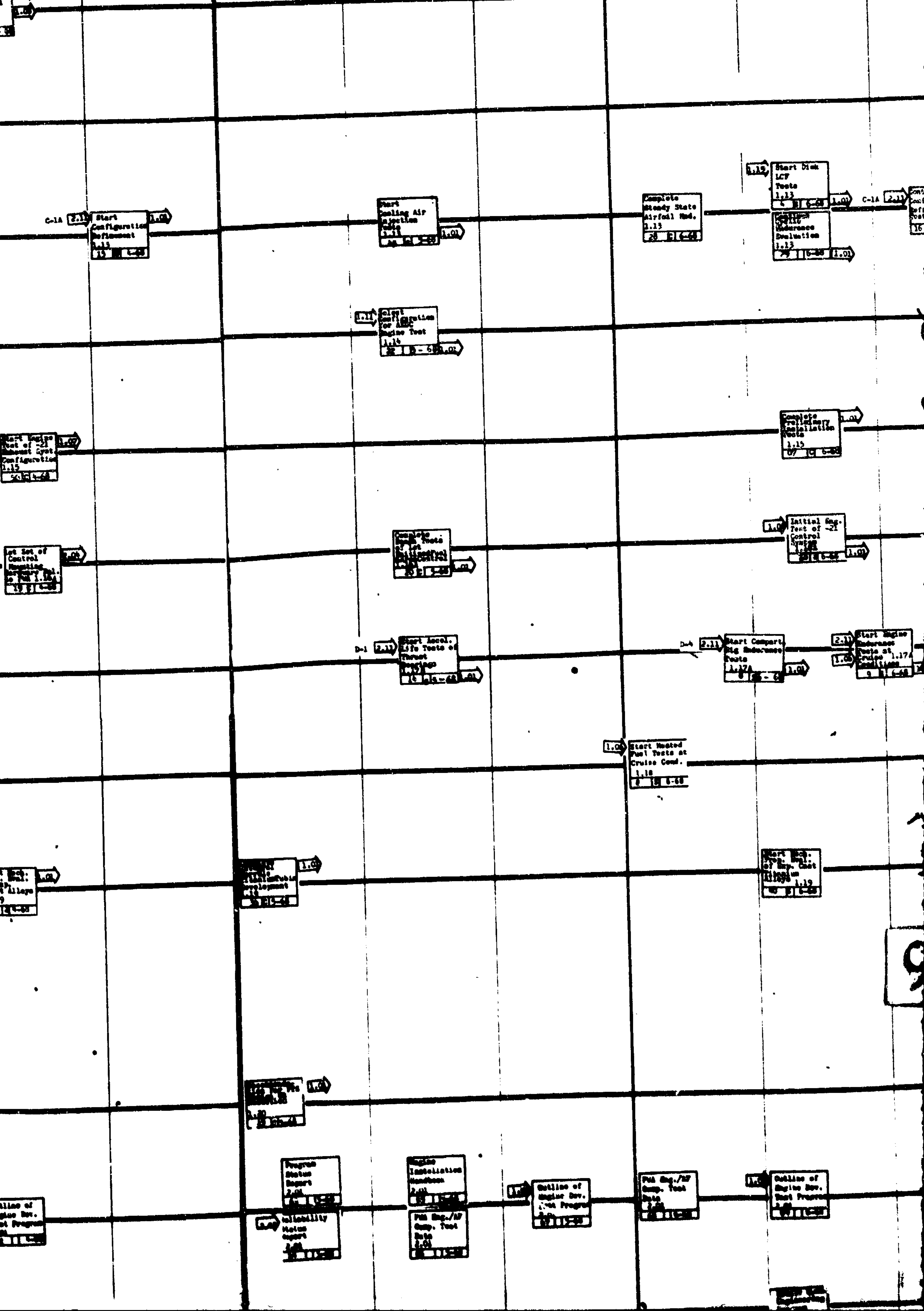

NOV
DEC
Complete C-1? Test Equip. Installation 1.05
10-68
t AEDC
ne Tests
1.08
1.07
Start Durability Supporting Tests 1.06
39 10-68
1.01
Complete Procurement for 10th Dev. Engine 1.02
22 12-68
System Equip
2.11
66 12-68
1.06
2.11
Containment
1.11
12-68
1.01
1.11
12-68
1.00
6

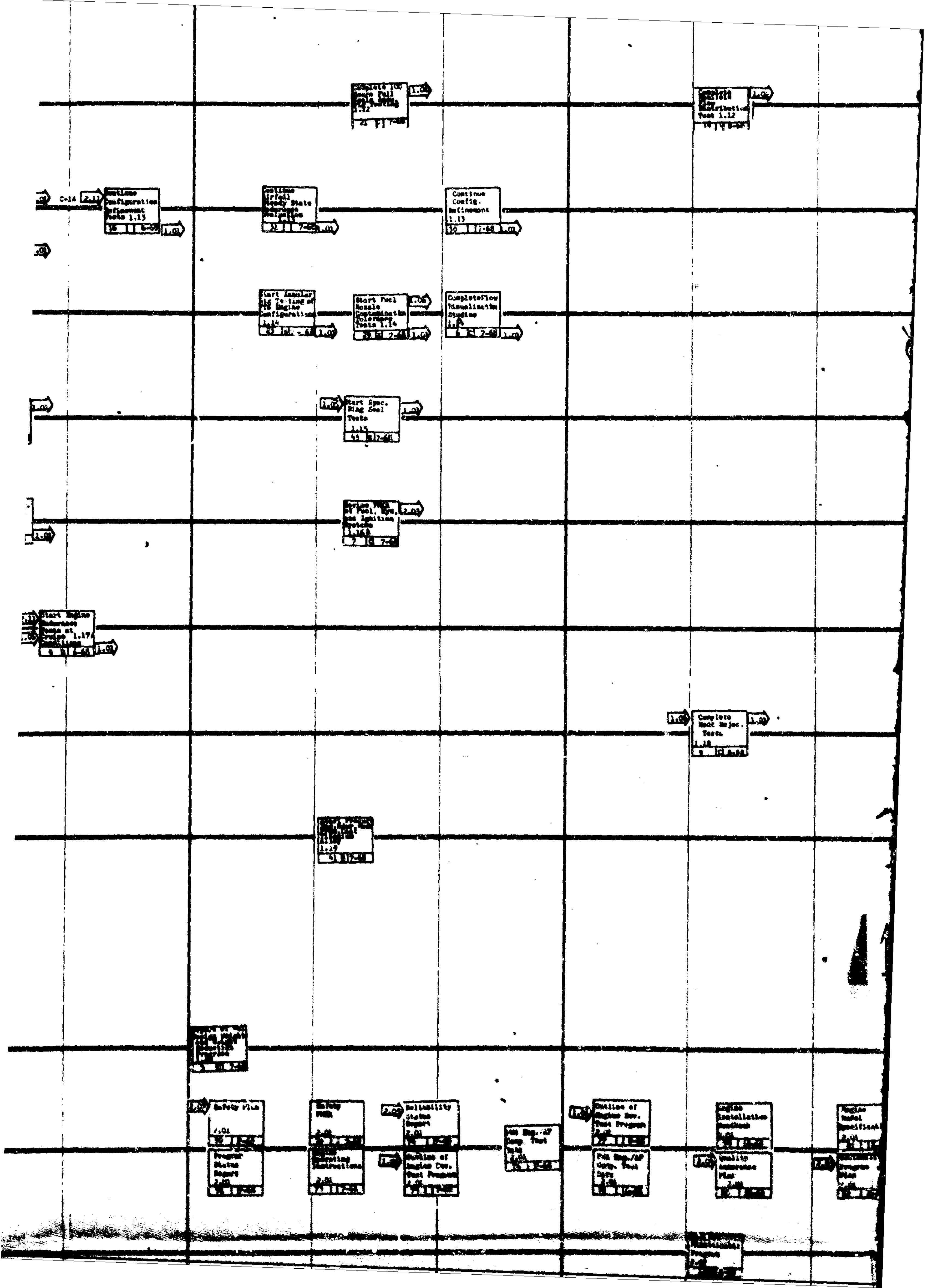


PRIMARY COMBUSTOR
1.12
TURBINE
1.13
AUGMENTOR
1.14
EXHAUST SYSTEM
1.15
CONTROLS AND ACCESSORIES
1.16
LUBRICANTS, LUBRICATION SYSTEM,
BEARINGS, SEAL, AND GEARS
1.17
FUELS
1.18
MANUFACTURING TECHNIQUES
AND MATERIALS
1.19
WEIGHT CONTROL AND STATUS
1.20
COORDINATION
2.01
Complete 3rd Stage Vane Tests 1.13
Complete Coordinated Installation Design
Device FMEA of Fuel, Hyd. & Ignition System
Complete Mechanical Actuator Study
Start Tests of Towershaft Bearings
Start Tests of Gearbox and Lube System Rig
Safety FMEA 2.01
Program Status Report 2.01
Outline of Engine Dev. Test Program 2.01
Reliability Status Report 2.01
Reliability Program Plan 2.01
Engine Installation Handbook 2.01
Outline of Engine Dev. Test Program 2.01

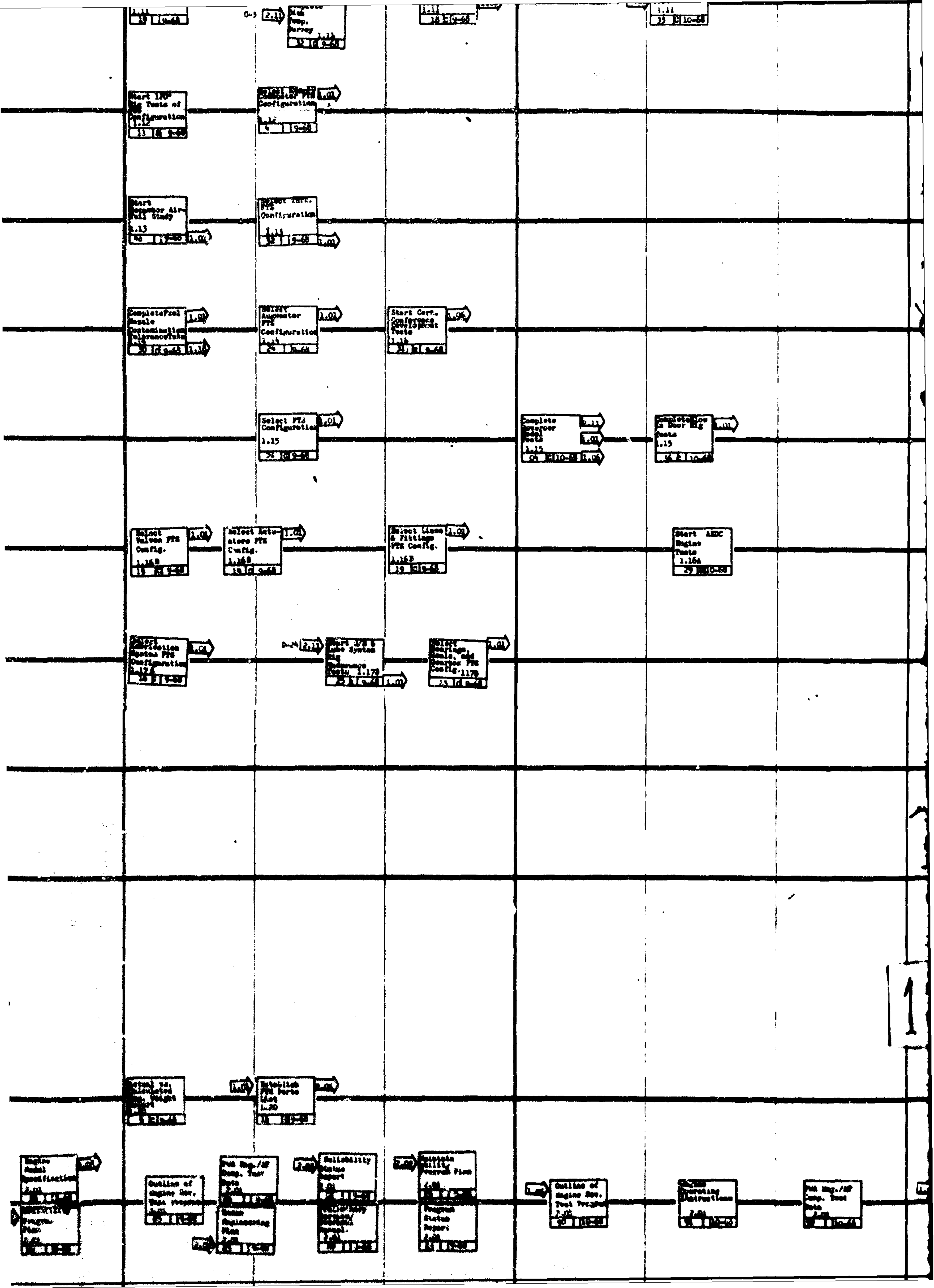


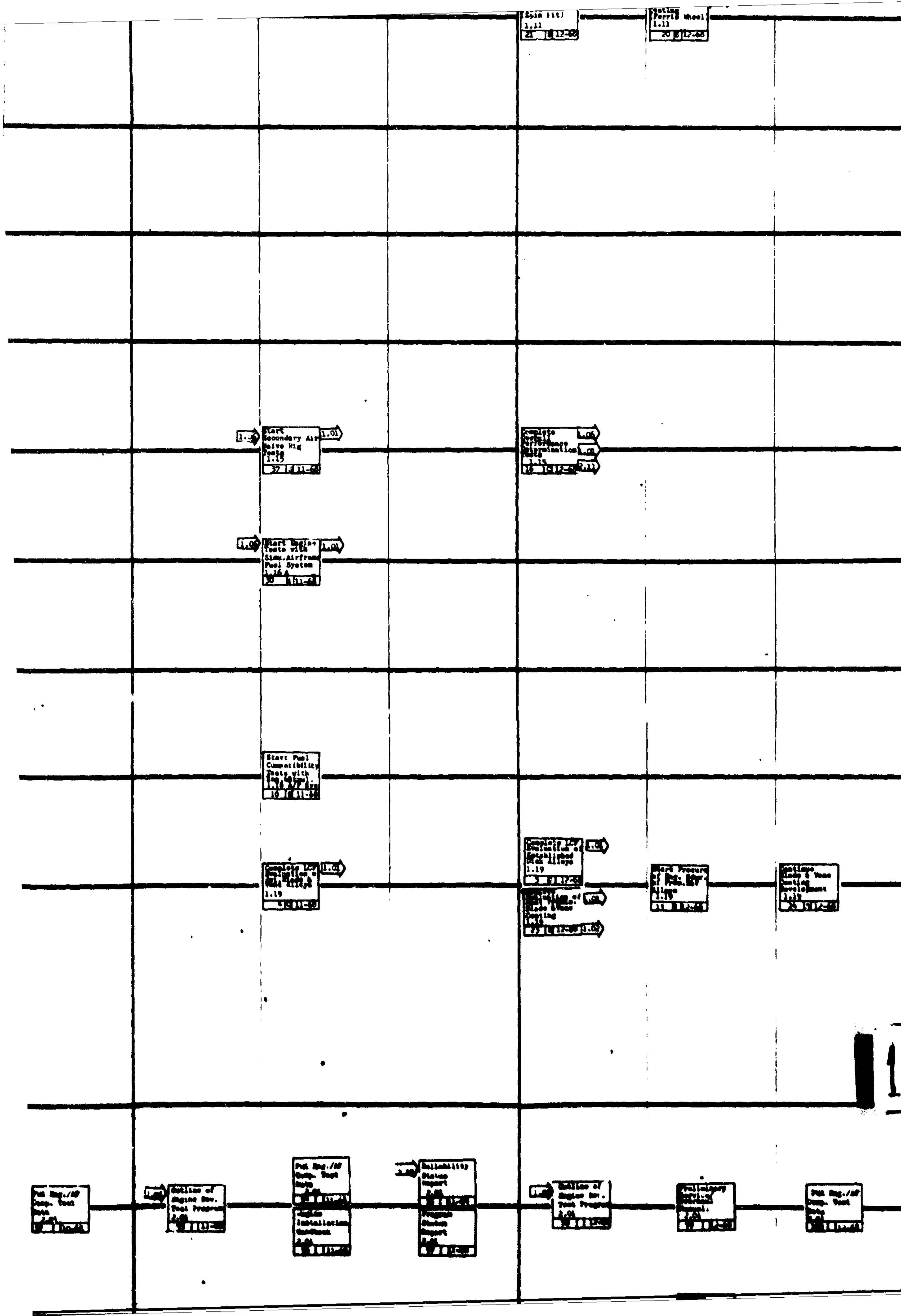
Start Coal.
Air Circuit
Evaluation
1.13
Complete Coal.
Air Circuit
Evaluation
1.13
Safety Plan
Program
Status
Report
Outline of
Engine Dev.
Test Program
Reliability
Status
Report


Start Configuration Refinement 1.15
Start Cooling Air Injection Tests 1.11
Complete Steady State Airfoil Mod. 1.13
Start Disk LCF Tests 1.13
Select Configuration for ASSC Engine Test 1.14
Complete Preliminary Installation Tests 1.15
Initial Eng. Test of -21 Control System
Start Accel. Life Tests of Thrust Reverser
Start Compart. Rig Endurance Tests 1.17A
Start Engine Endurance Tests at Cruise Conditions 1.17A
Start Heated Fuel Tests at Cruise Cond. 1.18
Start Eng. Prog. Eval. of Eng. Cast Titanium Alloys 1.19
Program Status Report 2.01
Reliability Status Report 2.01
Engine Installation Handbook 2.01
PWA Eng./AF Comp. Test Data 2.01
Outline of Engine Dev. Test Program

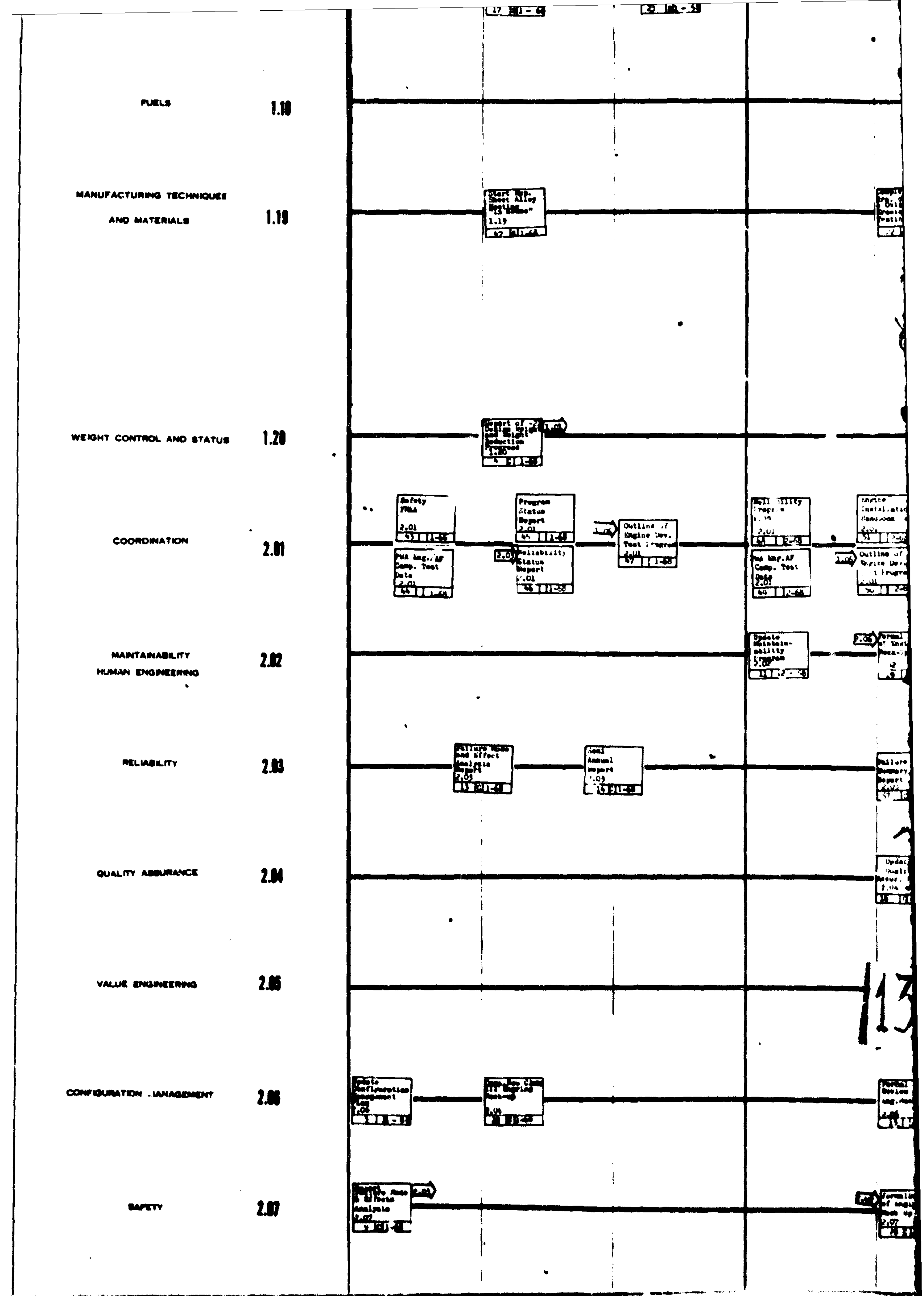


Continue Configuration Refinement Tests 1.13
Continue Config. Refinement 1.13
Start Fuel Nozzle Contamination Tolerance Tests 1.14
Start Sync. Ring Seal Tests 1.15
Complete Heat Injec. Tests 1.18
Safety Plan 2.01
Reliability Status Report 2.01
Program Status Report 2.01
Outline of Engine Dev. Test Program
Engine Installation Handbook
Quality Assurance Plan

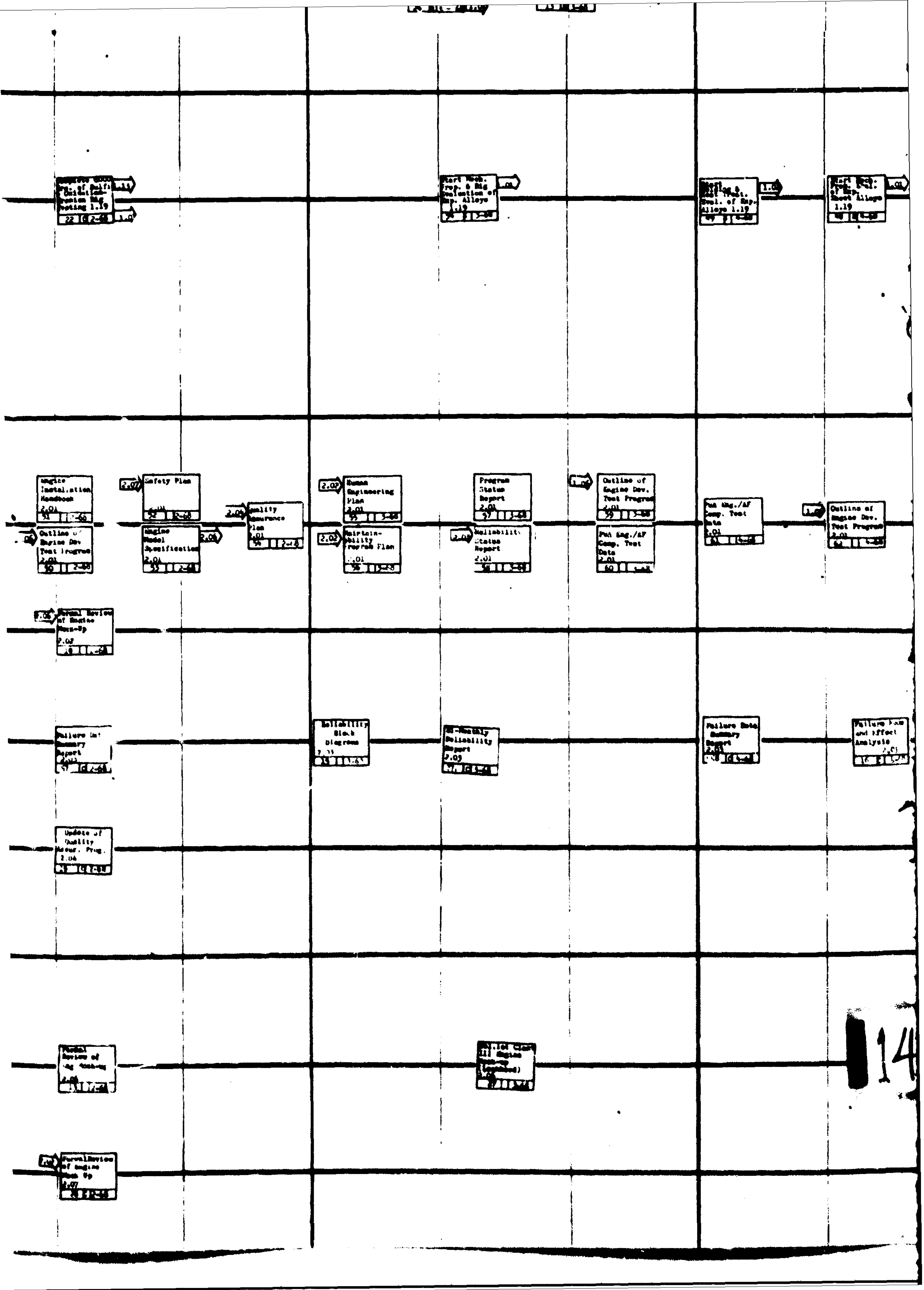

Start 120° Rig Tests of Configuration 1.12
Compressor PTS Configuration
Start Combustor Air-Wall Study 1.13
Select Turb. PTS Configuration
Augmentor PTS Configuration
Start Corr. Conference Development Tests
Select PTS Configuration 1.15
Complete Model Tests 1.15
Select Valves PTS Config. 1.16B
Select Actuators PTS C'nfig. 1.16B
Select Lines & Fittings PTS Config. 1.16B
Start AEDC Engine Tests 1.16A
Lube System Rig Endurance Tests 1.17B
Gearbox PTS Config. 1.17B
Establish PTS Parts List 1.20
Engine Model Specification
Outline of Engine Dev. Test Program
Reliability Status Report
Program Status Report
Outline of Engine Dev. Test Program
Operating Instructions
1


Start Secondary Air Valve Rig Tests
Start Engine Tests with Simu. Airframe Fuel System
Outline of Engine Dev. Test Program
Reliability Status Report
Engine Installation Handbook
Program Status Report

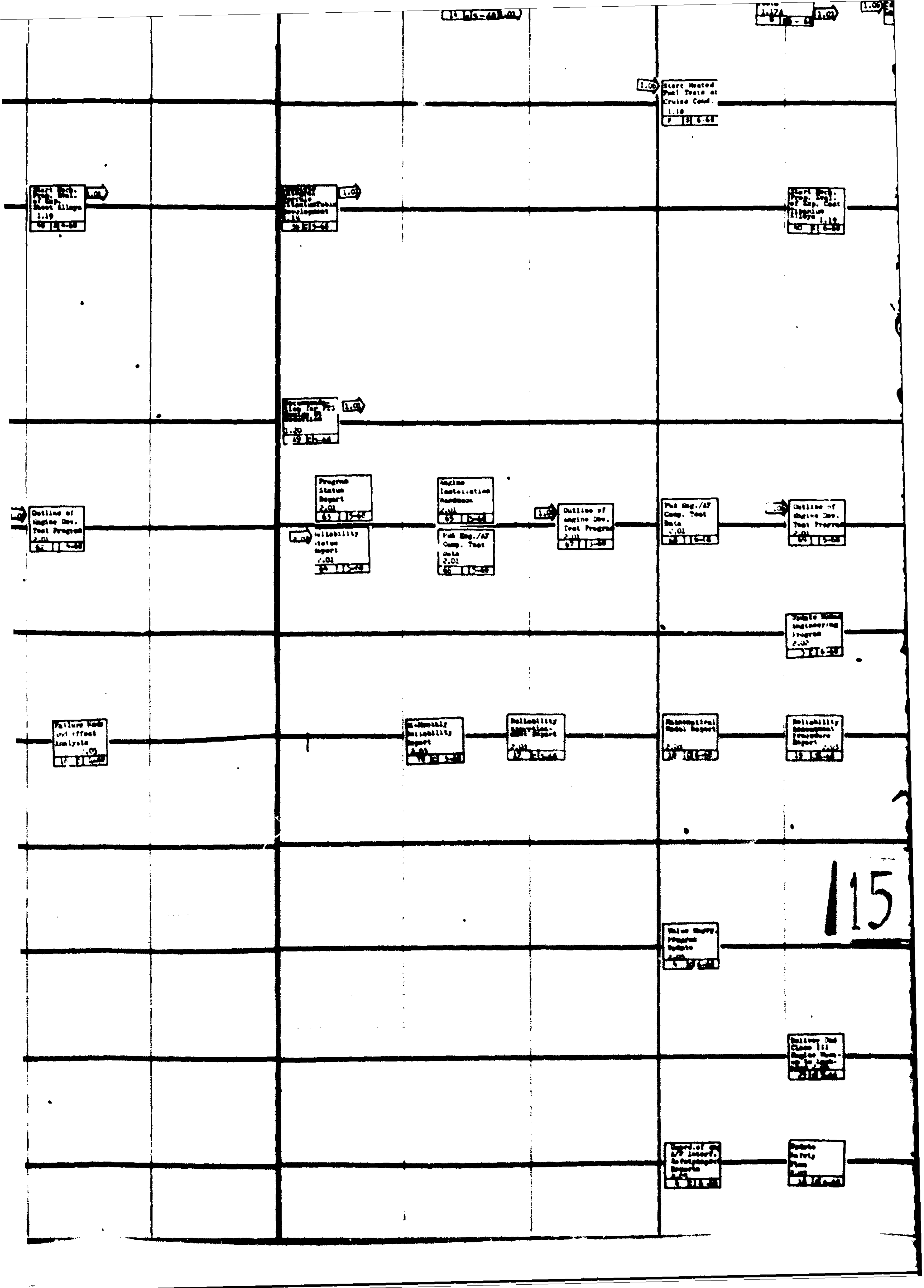
12



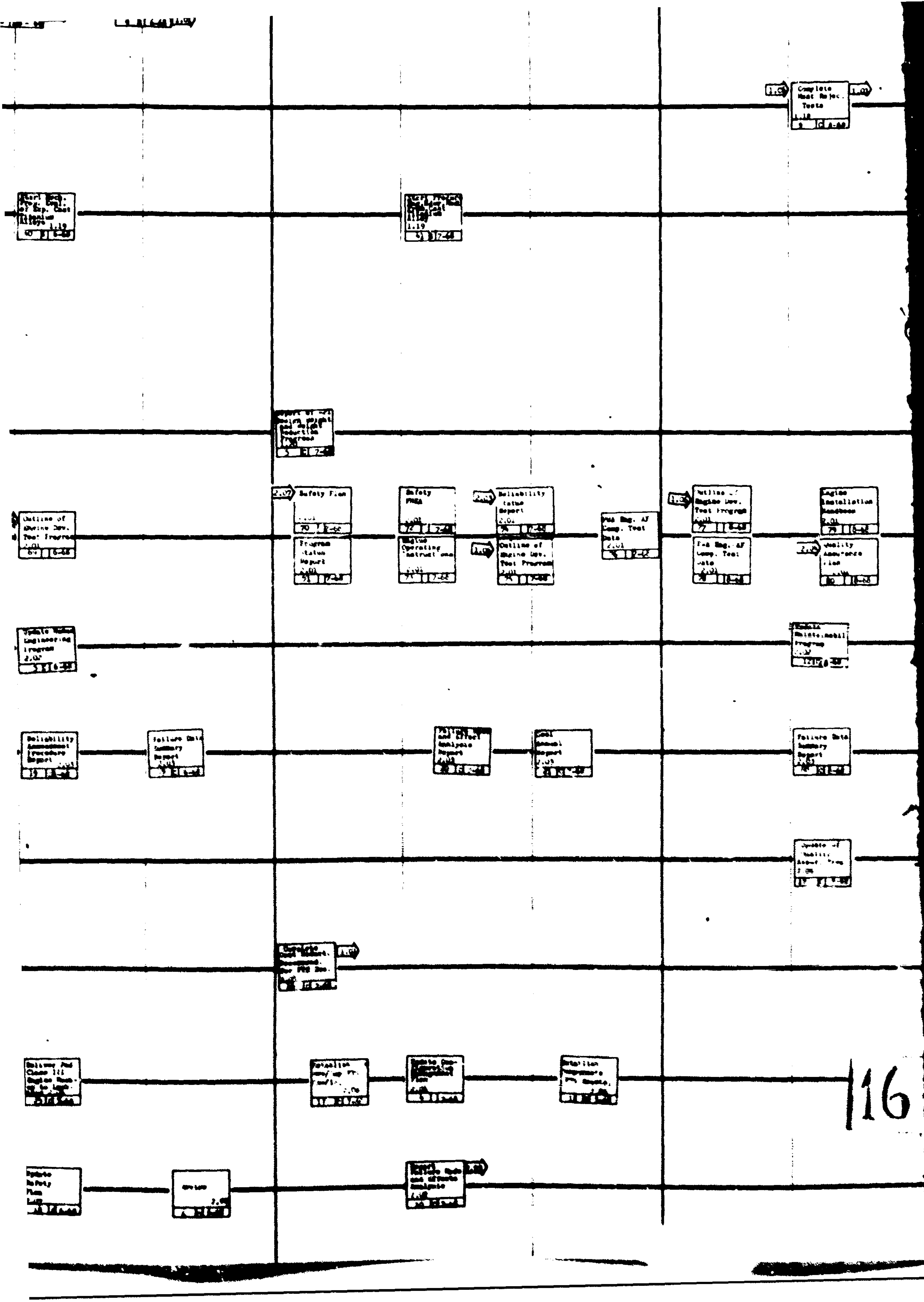
FUELS
1.18
MANUFACTURING TECHNIQUES
AND MATERIALS
1.19
Start Reb. Sheet Alloy
1.19
WEIGHT CONTROL AND STATUS
1.20
COORDINATION
2.01
Safety FMEA
2.01
Program Status Report
2.01
Reliability Status Report
Outline of Engine Dev. Test Program
MAINTAINABILITY
HUMAN ENGINEERING
2.02
Update Maintainability Program
RELIABILITY
2.03
Failure Mode and Effect Analysis Report
Semi Annual Report
Failure Summary Report
QUALITY ASSURANCE
2.04
VALUE ENGINEERING
2.05
CONFIGURATION MANAGEMENT
2.06
Update Configuration Management Plan
SAFETY
2.07
Analysis
2.07



Start Mech. Prop. & Eng. Evaluation of Exp. Alloys 1.19
Engine Installation Handbook 2.01
Outline of Engine Dev. Test Program 2.01
Safety Plan 2.01
Engine Model Specification 2.01
Quality Assurance Plan 2.01
Human Engineering Plan 2.01
Maintainability Program Plan 2.01
Program Status Report 2.01
Reliability Status Report 2.01
Outline of Engine Dev. Test Program 2.01
PMA Eng./AF Comp. Test Data 2.01
Outline of Engine Dev. Test Program 2.01
Formal Review of Engine Mock-Up 2.02
Failure Data Summary Report
Reliability Block Diagrams
Bi-Monthly Reliability Report 2.03
Failure Data Summary Report 2.03
Failure Mode and Effect Analysis
Update of Quality Assur. Prog. 2.04
Formal Review of Engine Mock-Up 2.07
14

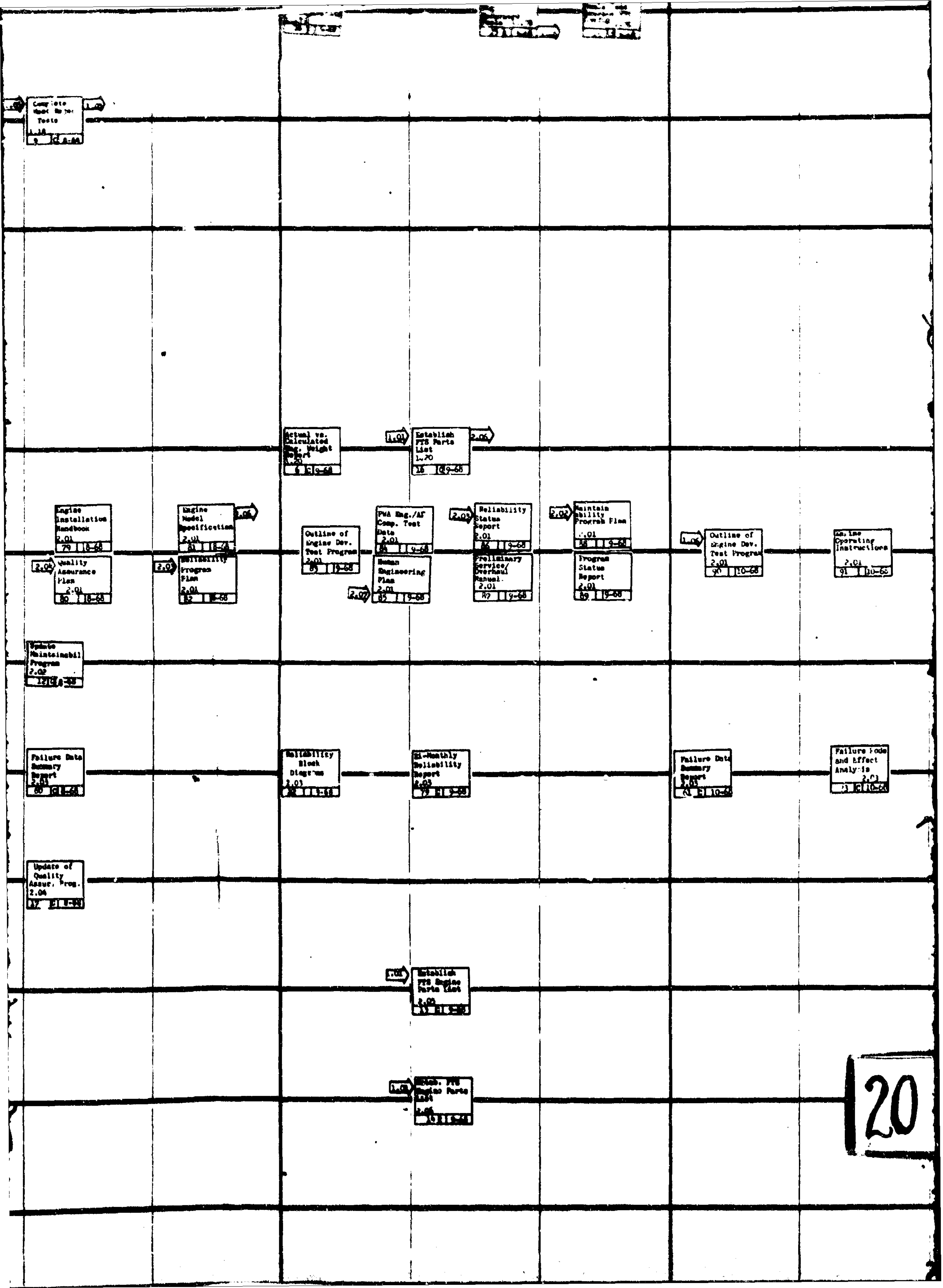


Start Heated Fuel Tests at Cruise Cond.
1.18
Outline of Engine Dev. Test Program
2.01
Program Status Report
2.01
Engine Installation Handbook
Reliability Status Report
2.01
P&A Eng./AF Comp. Test Data
2.01
Failure Mode and Effect Analysis
Update Safety Plan

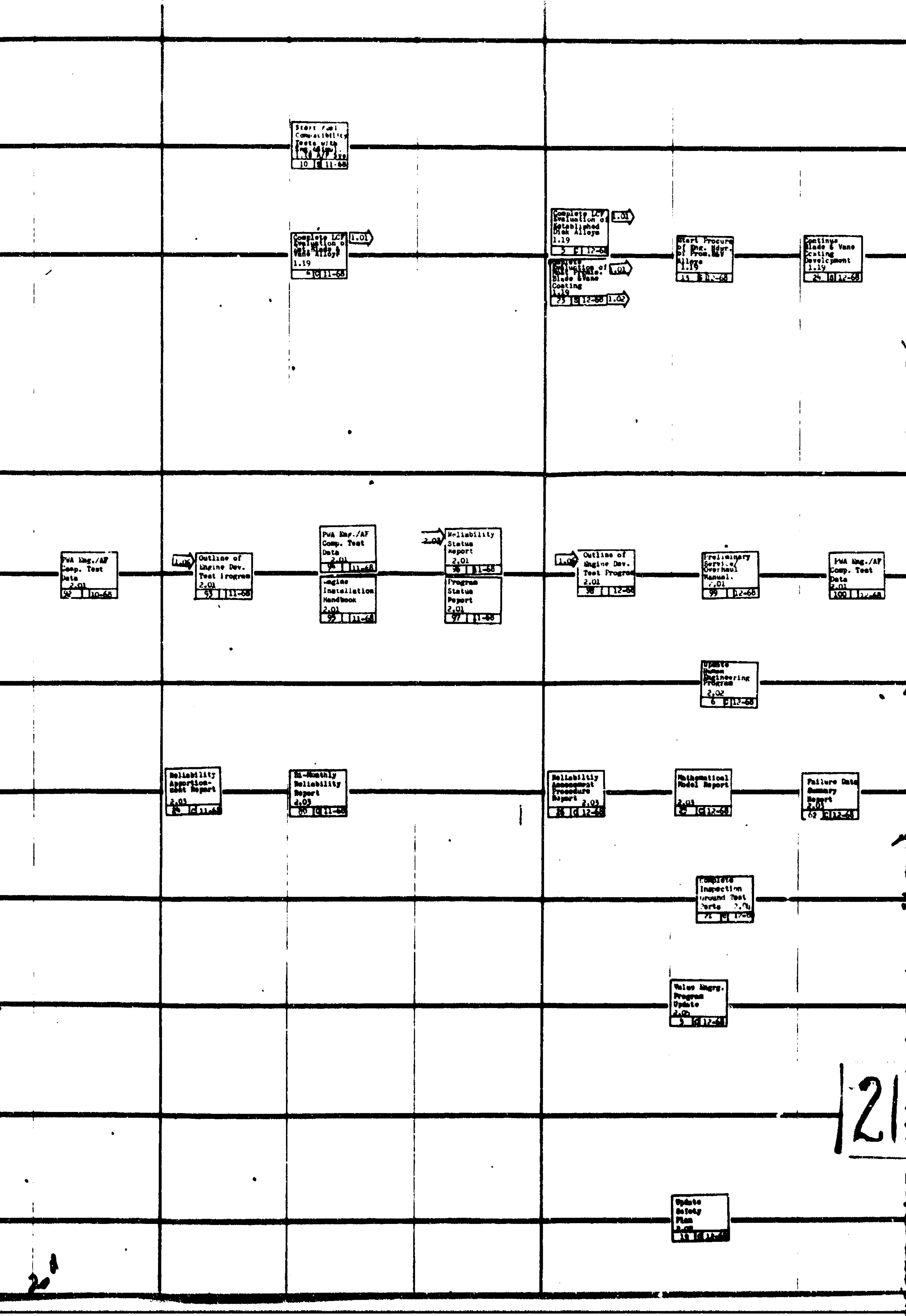


Complete Heat Rejec. Tests
Safety Plan
Safety FMEA
Reliability Status Report
Outline of Engine Dev. Test Program
Program Status Report
Engine Installation Handbook
Quality Assurance Plan
Reliability Assessment Procedure Report
Failure Data Summary Report
Failure Mode and Effect Analysis Report
Failure Data Summary Report
Update Safety Plan

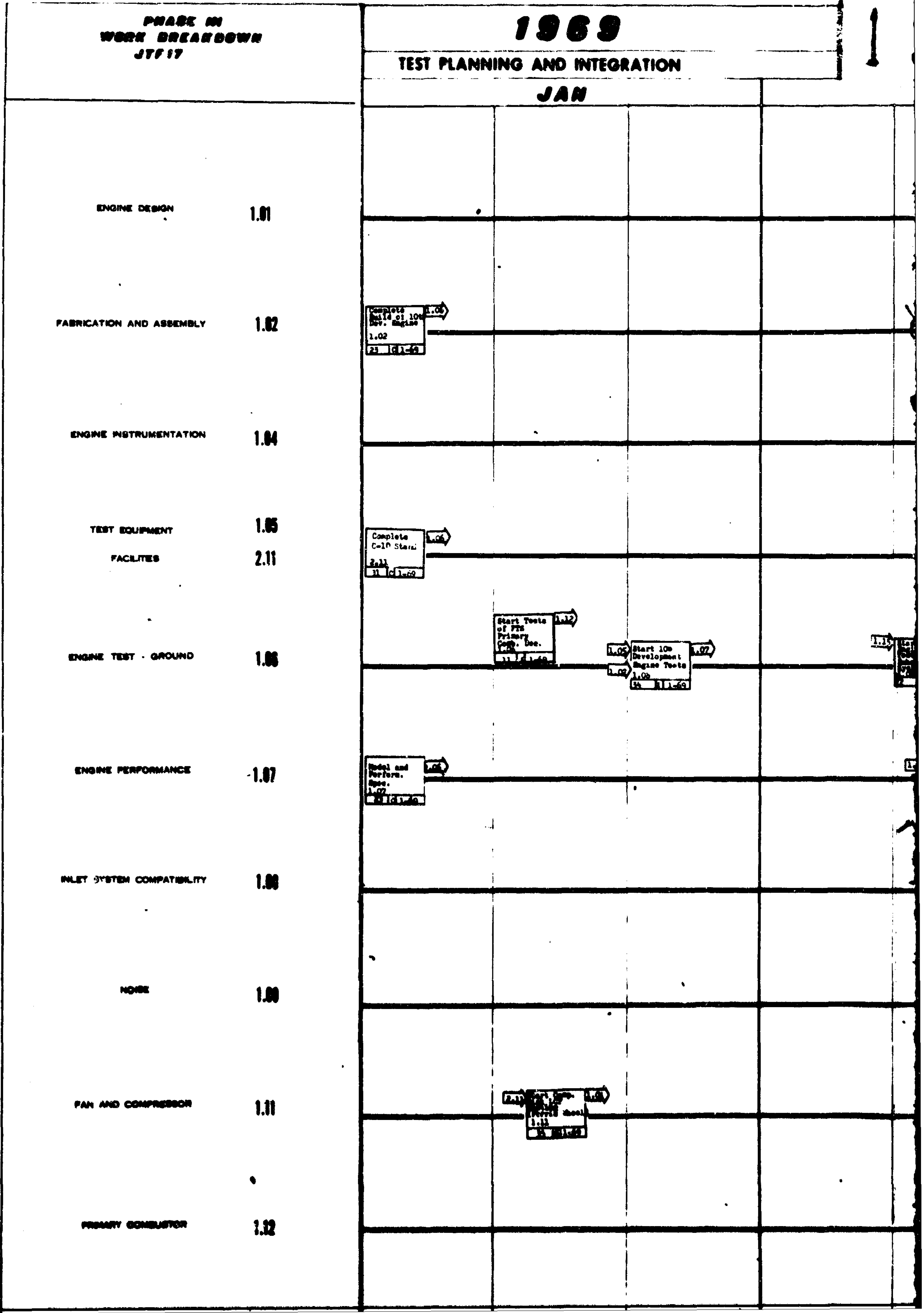
16

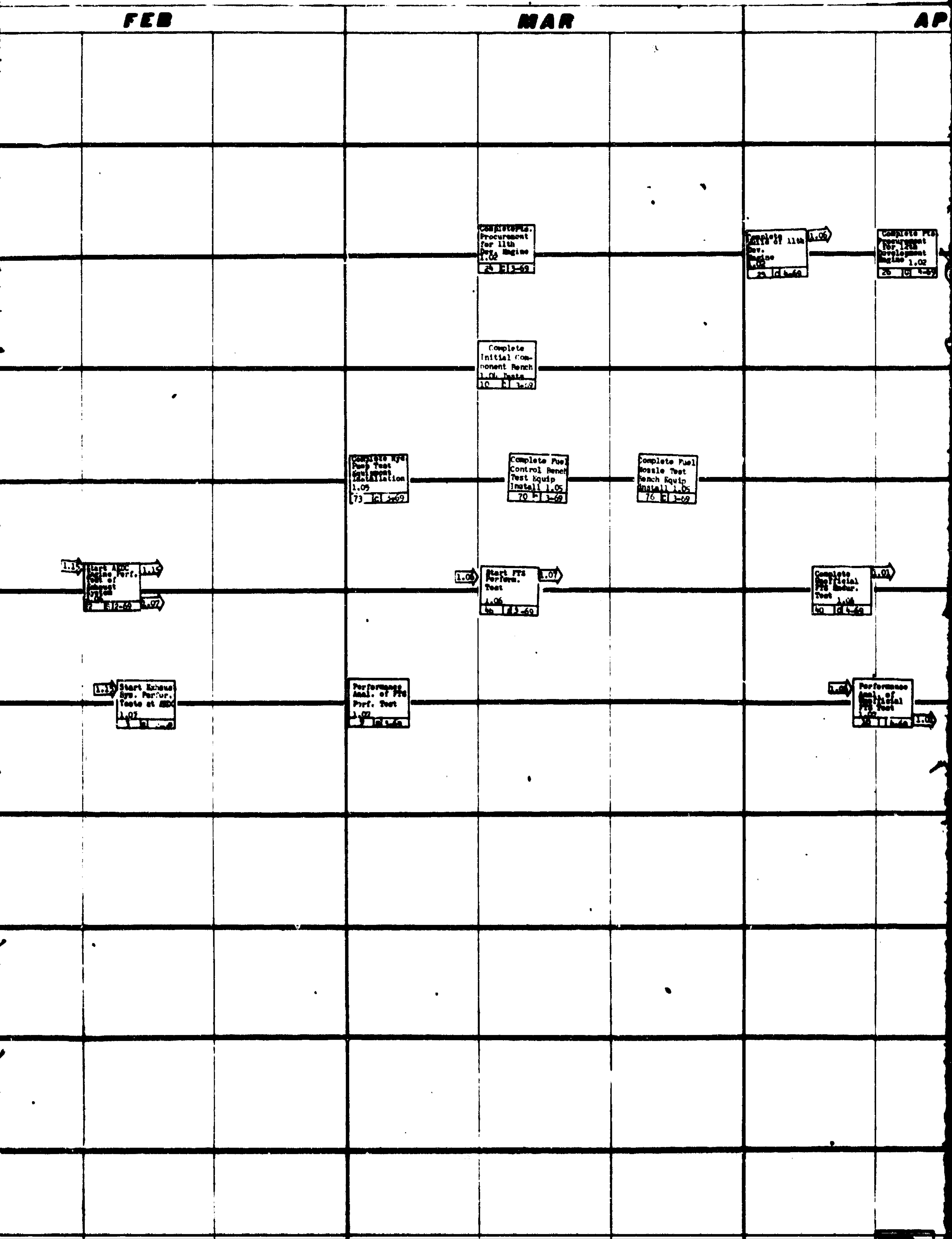


Complete Mode Major Tests
Actual vs. Calculated Eng. Weight Report
Establish PTS Parts List
Engine Installation Handbook
Engine Model Specification
Outline of Engine Dev. Test Program
PWA Eng./AF Comp. Test Data
Reliability Status Report
Maintainability Program Plan
Outline of Engine Dev. Test Program
Engine Operating Instructions
Quality Assurance Plan
Reliability Program Plan
Human Engineering Plan
Preliminary Service/Overhaul Manual
Program Status Report
Update Maintainability Program
Failure Data Summary Report
Reliability Block Diagrams
Bi-Monthly Reliability Report
Failure Data Summary Report
Failure Mode and Effect Analysis
Update of Quality Assur. Prog.
Establish PTS Engine Parts List
Estab. PTS Engine Parts List
20



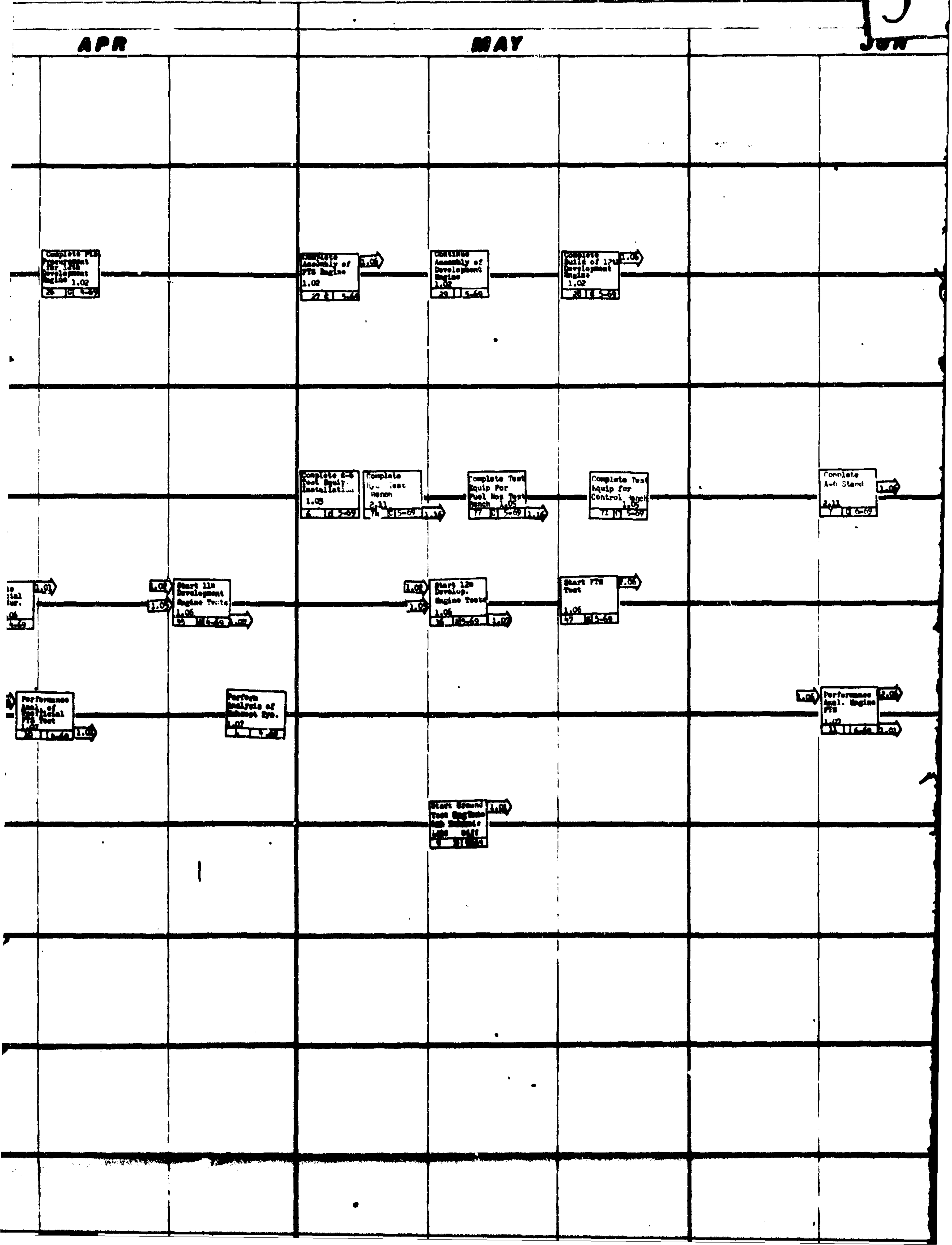
Complete LCF Evaluation of Blade & Vane Alloys 1.19 11-68
1.01
Complete LCF Evaluation of Established Disk Alloys 1.19 5 12-68
1.01
Blade & Vane Coating 1.19 23 12-68
1.01
1.02
Start Procure of Eng. Hdwr. Alloys 1.19 12-68
Continue Blade & Vane Coating Development 1.19 24 12-68
PWA Eng./AF Comp. Test Data 2.01 92 10-68
Outline of Engine Dev. Test Program 2.01 93 11-68
PWA Eng./AF Comp. Test Data 11-68
Engine Installation Handbook 2.01 95 11-68
Reliability Status Report 2.01 96 11-68
Program Status Report 2.01 97 11-68
Outline of Engine Dev. Test Program 2.01 98 12-68
Preliminary Overhaul Manual 99 12-68
PWA Eng./AF Comp. Test Data 2.01 100
Update Human Engineering Program 2.02 6 12-68
Reliability Apportionment Report 2.03 11-68
Bi-Monthly Reliability Report 2.03 80 11-68
Reliability Assessment Procedure Report 2.03 12-68
Mathematical Model Report 2.03 12-68
Failure Data Summary Report 2.03 62 12-68
Complete Inspection Ground Test Parts
Value Engrg. Program Update 2.05 5 12-68
Update Safety Plan
21
20


PHASE III
WORK BREAKDOWN
JTF17
1969
TEST PLANNING AND INTEGRATION
JAN
ENGINE DESIGN 1.01
FABRICATION AND ASSEMBLY 1.02
Complete Build of 10th Dev. Engine 1.02
1.06
ENGINE INSTRUMENTATION 1.04
TEST EQUIPMENT 1.05
FACILITIES 2.11
Complete C-10 Stand 2.11
1.06
ENGINE TEST - GROUND 1.06
Start Tests of FTS Primary Comb. Dev.
1.12
1.05
1.02
Start 10th Development Engine Tests 1.06
34 1-69
1.07
ENGINE PERFORMANCE 1.07
Model and Perform. Spec. 1.07
1.06
INLET SYSTEM COMPATIBILITY 1.08
NOISE 1.09
FAN AND COMPRESSOR 1.11
2.11
1.11
1.06
PRIMARY COMBUSTOR 1.12



FEB
MAR
AP
Complete Pts. Procurement for 11th Dev. Engine 1.02
Complete Initial Component Bench 1.04 Tests
Complete Hyd. Pump Test Equipment Installation 1.05
Complete Fuel Control Bench Test Equip Install 1.05
Complete Fuel Nozzle Test Bench Equip Install 1.05
Start Exhaust Sys. Perfor. Tests at AEDC 1.07
Performance Anal. of PTS Perf. Test
Start PTS Perform. Test 1.06
Complete Official PTS Endur. Test
Performance Anal. of Official PTS Test
Complete Pts. Procurement for 12th Development Engine 1.02

TEST PLANN


APR
MAY
JUN
Complete PTS Procurement for 12th Development Engine 1.02
Complete Assembly of PTS Engine 1.02
1.06
Continue Assembly of Development Engine 1.02
29 5-69
Complete Build of 12th Development Engine 1.02
1.06
Complete Test Equip Installation 1.05
Complete Test Bench 2.11
1.14
Complete Test Equip For Fuel Nos Test Bench 1.05
Complete Test Equip for Control Bench 1.05
Complete A-6 Stand 2.11
1.06
1.01
Start 11th Development Engine Tests 1.06
Start 12th Develop. Engine Tests 1.06
1.07
Start PTS Test 1.06
Performance Anal. of PTS Test 1.07
Perform Analysis of Exhaust Sys. 1.07
Performance Anal. Engine PTS 1.07
Start Ground Test

1969

JUN	JUL	AUG

CONTINUE DESIGN SUPPORT OF ENGINE FOR 100 HOURS FLIGHT TEST

Complete A-6 Stand
2.11
1.04

Complete A-7 Test Equip. Installation
1.05
9 C 7-69

Complete A-7 Stand
2.11

Complete FTS Test
1.06
2.06

CONTINUE ENGINE TESTS IN SUPPORT OF 100 HOURS FLIGHT TE

Performance Anal. Engine FTS
1.07
2.06
1.01

Model and Perform. Sync.
1.08
2.08

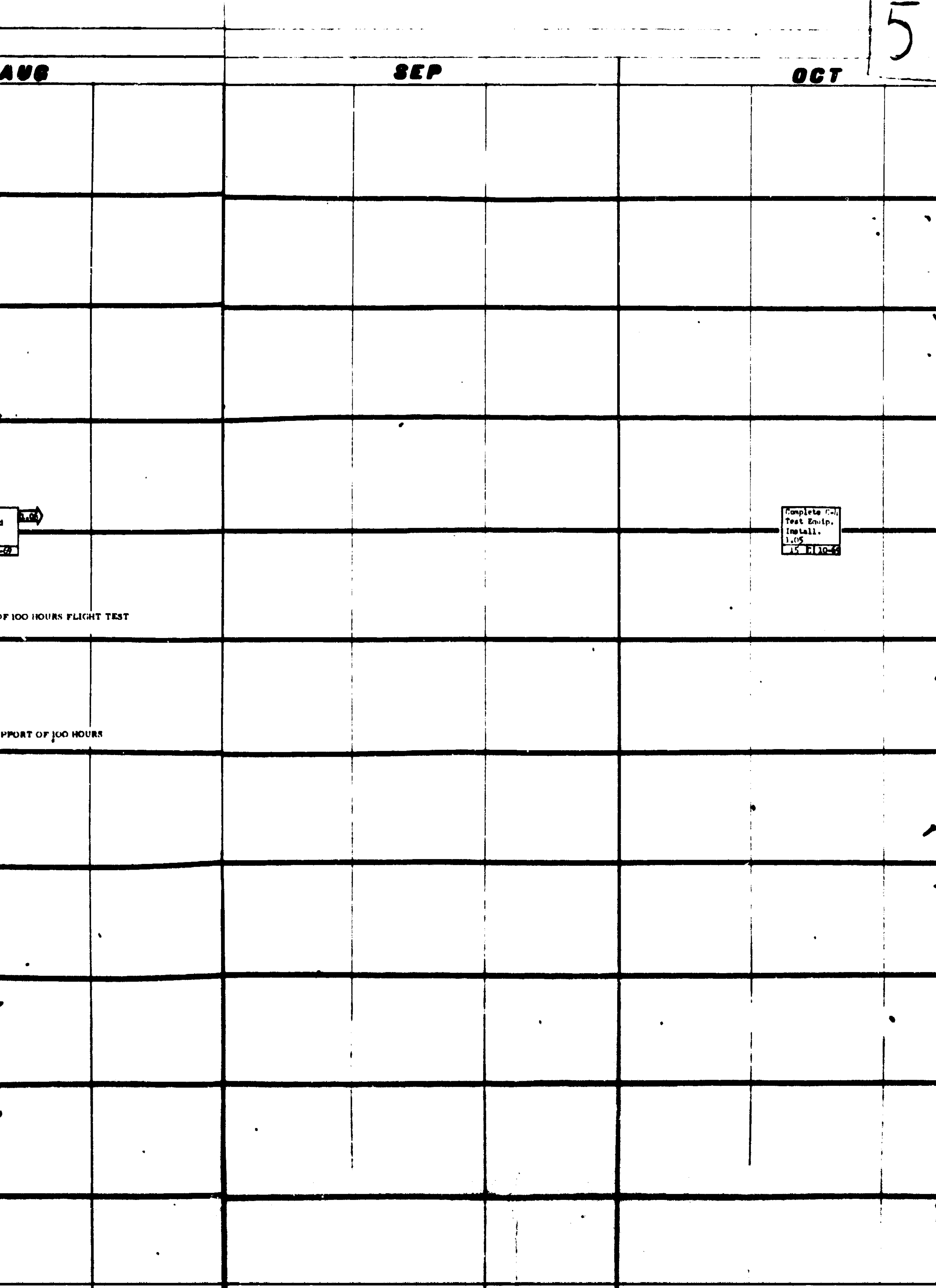
CONTINUE ENGINE PERFORMANCE EVALUATIONS IN SUPPORT OF 100 HOURS

CONTINUE INLET COMPATIBILITY TESTS IN SUPPORT OF 100 HOURS FLIGHT

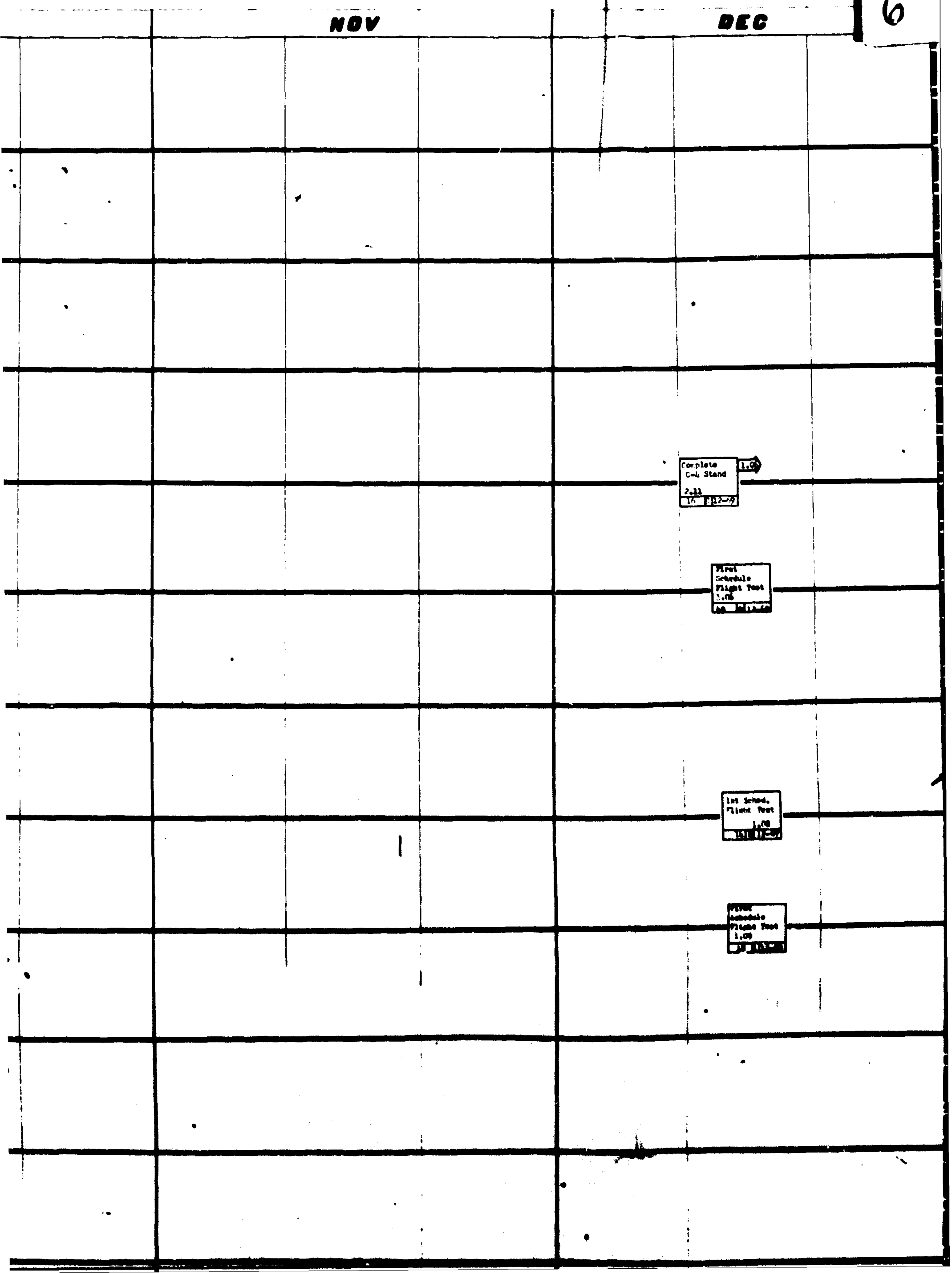
CONTINUE NOISE TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST

CONTINUE FAN AND COMPRESSOR TESTS IN SUPPORT OF 100 HOURS FLIGHT

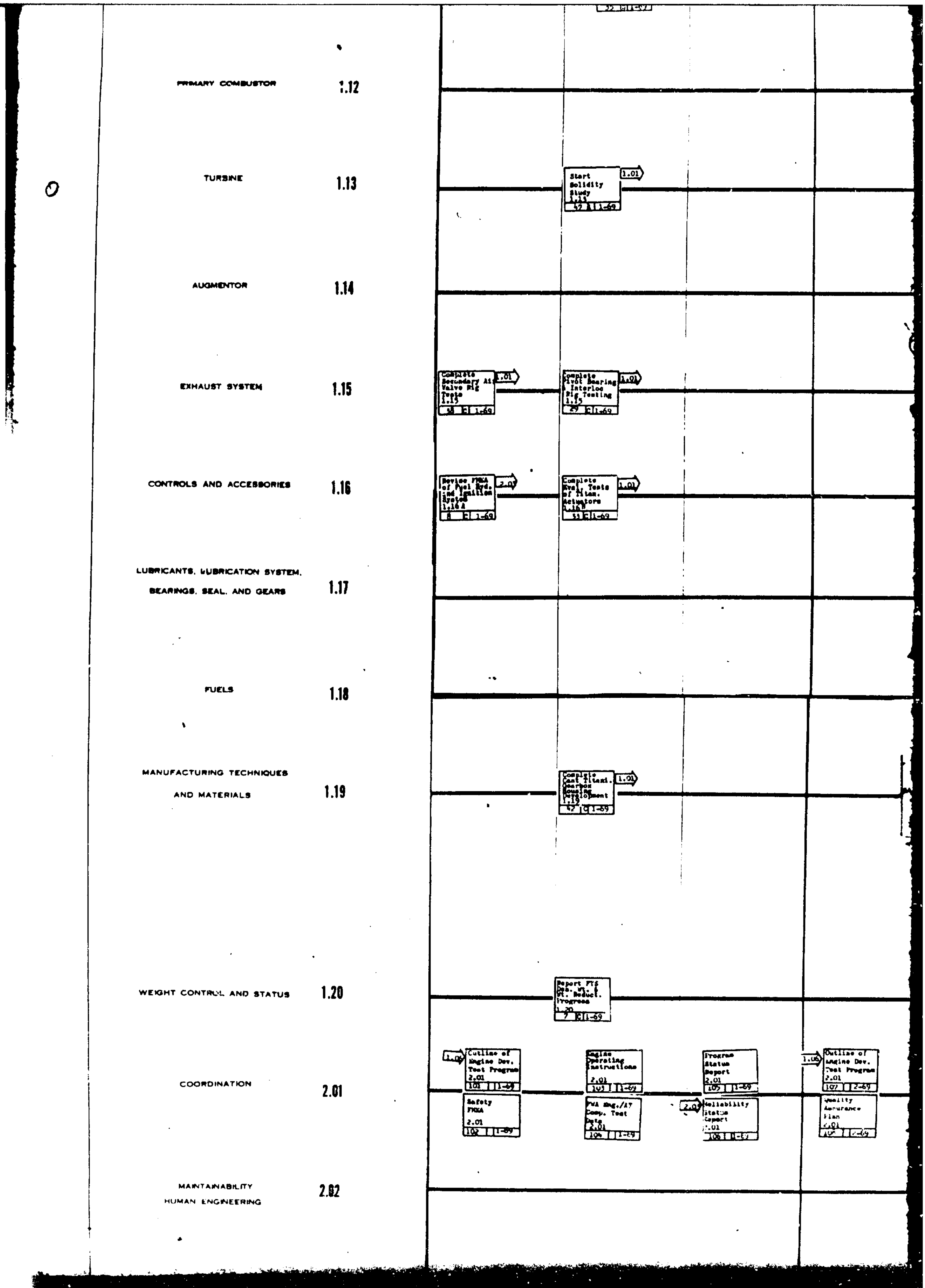
CONTINUE PRIMARY COMBUSTOR TESTS IN SUPPORT OF 100 HOUR FLIGHT TEST

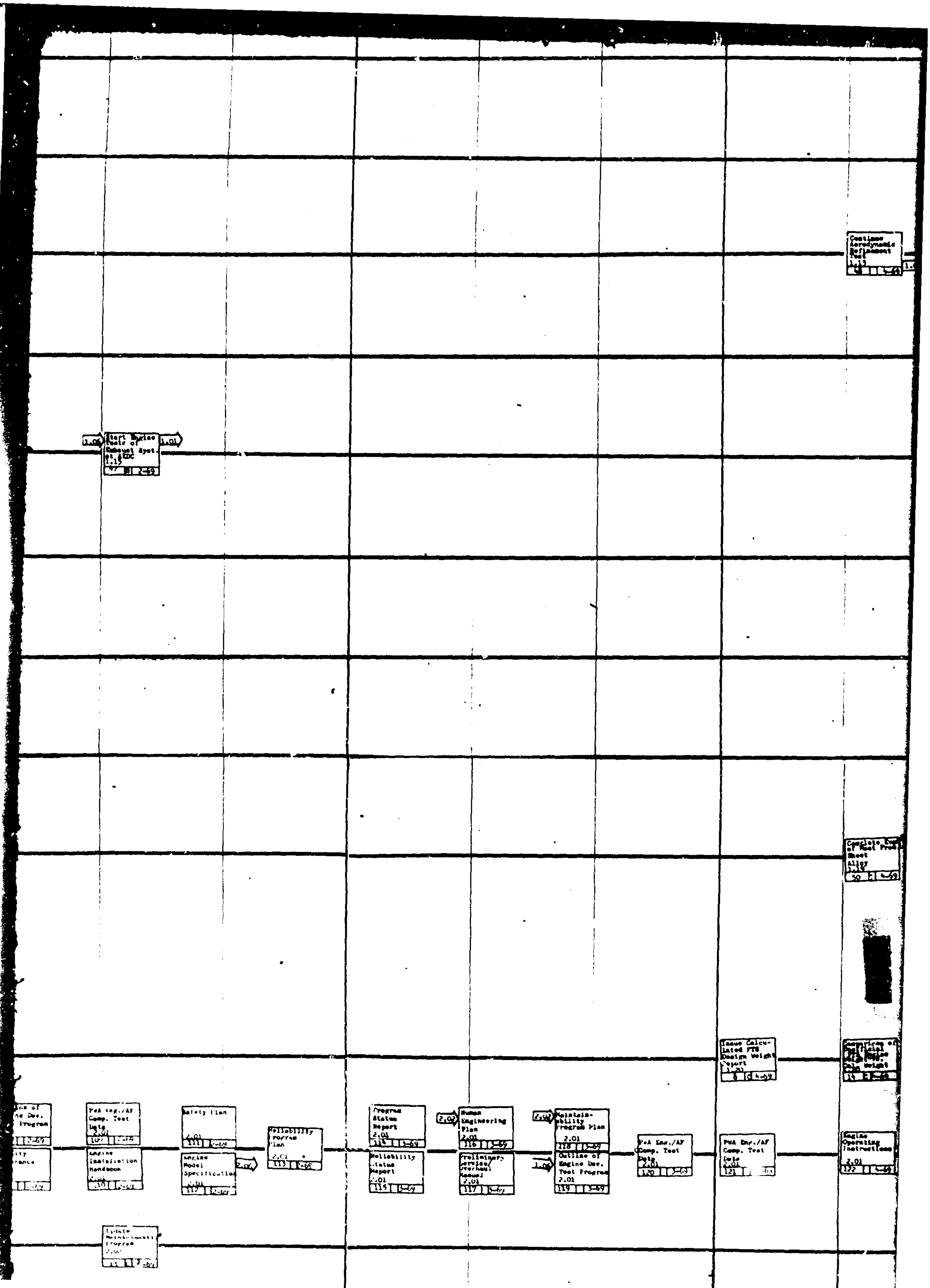

5
AUG
SEP
OCT
1.05
Complete C-l
Test Equip.
Install.
1.05
OF 100 HOURS FLIGHT TEST
PPORT OF 100 HOURS

6

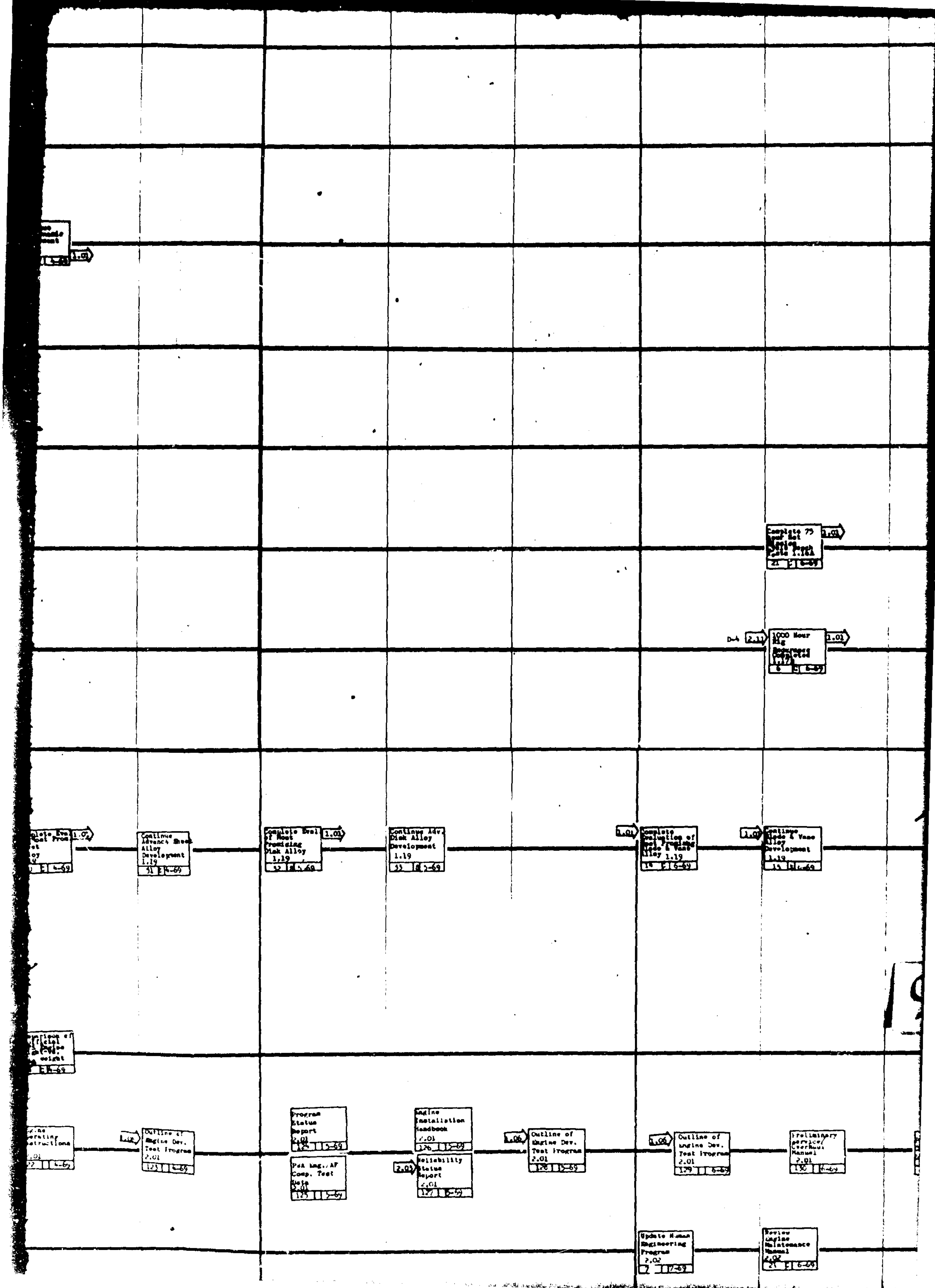


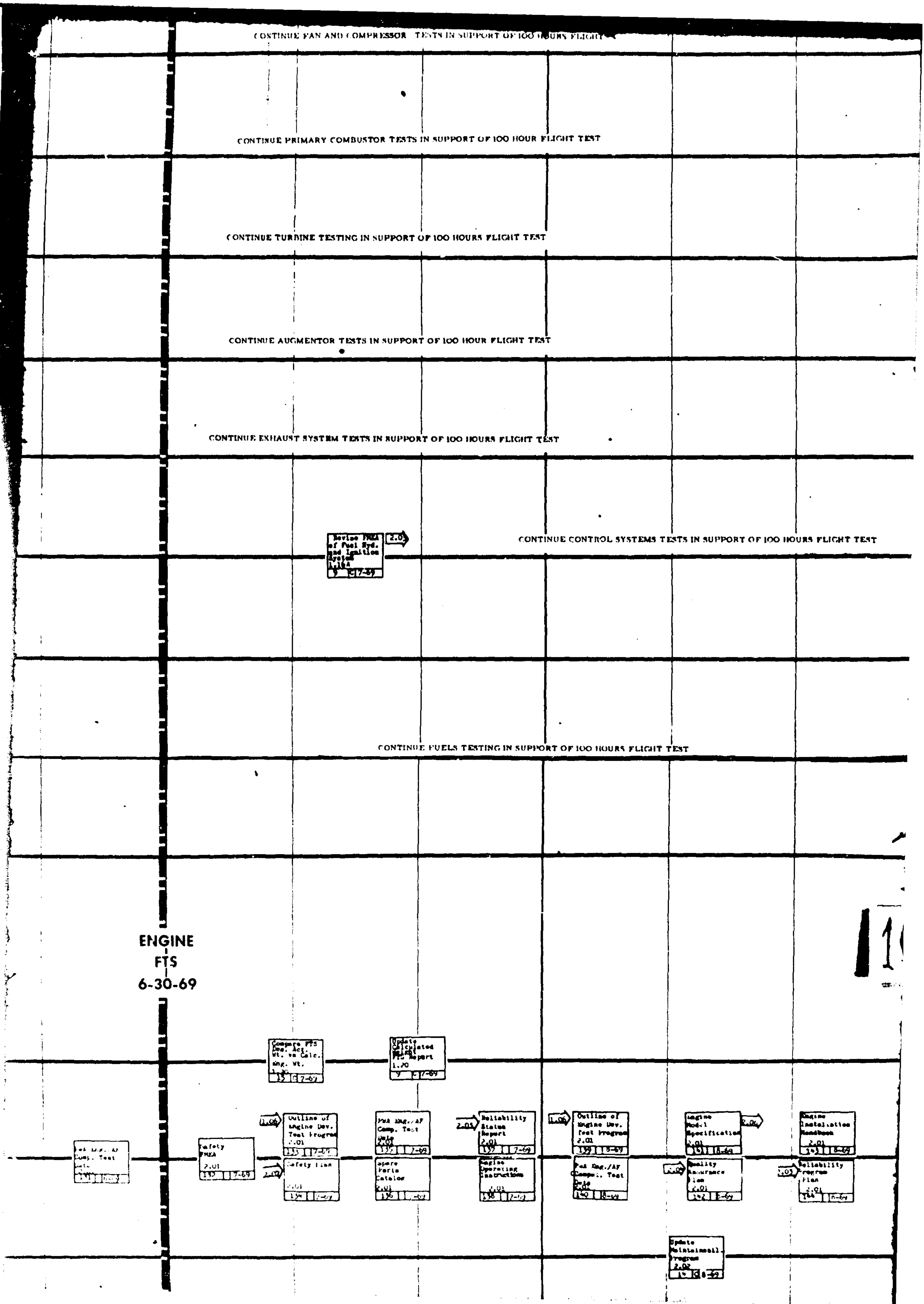
NOV
DEC
Complete
C-4 Stand
2.11
1.00
First
Schedule
Flight Test
1st Sched.
Flight Test
1.00
First
Schedule
Flight Test
1.00


PRIMARY COMBUSTOR
1.12
TURBINE
1.13
Start Solidity Study 1.13
1.01
AUGMENTOR
1.14
EXHAUST SYSTEM
1.15
Complete Secondary Air Valve Rig Tests 1.15
1-69
Complete Pivot Bearing & Interloc Rig Testing 1.15
29
1-69
CONTROLS AND ACCESSORIES
1.16
Complete Eval. Tests of Titan. Actuators
1-69
LUBRICANTS, LUBRICATION SYSTEM, BEARINGS, SEAL, AND GEARS
1.17
FUELS
1.18
MANUFACTURING TECHNIQUES AND MATERIALS
1.19
Complete Gearbox Housing Development 1.19
1-69
WEIGHT CONTROL AND STATUS
1.20
Report Progress 1.20
7
1-69
COORDINATION
2.01
Outline of Engine Dev. Test Program 2.01
101
1-69
Safety FMEA 2.01
102
Engine Operating Instructions 2.01
Program Status Report 2.01
105
Reliability Status Report
Outline of Engine Dev. Test Program 2.01
2-69
Quality Assurance Plan
2-69
MAINTAINABILITY HUMAN ENGINEERING
2.02

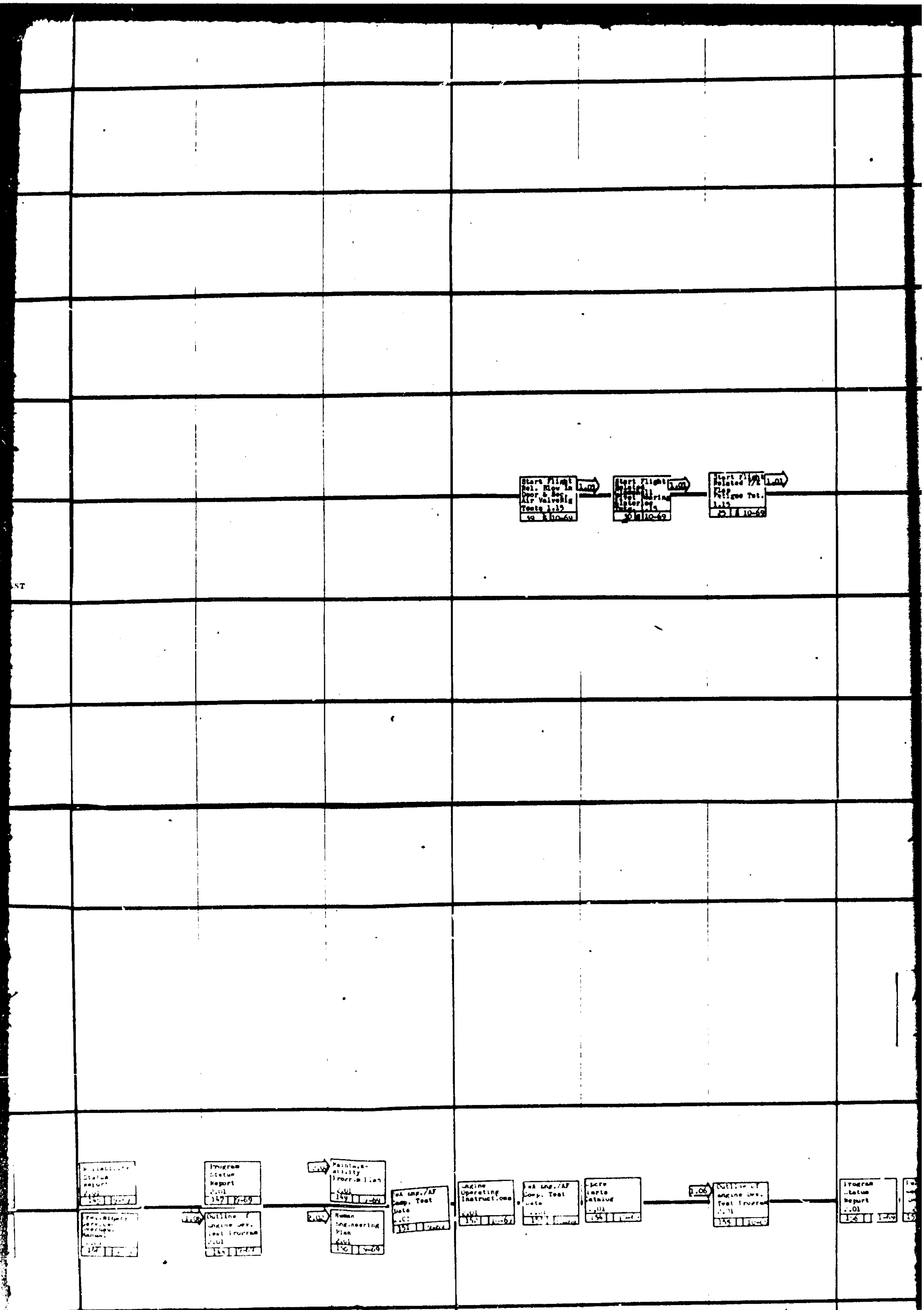


Continue Aerodynamic Refinement Test
Start Engine Tests of Exhaust Syst. at AEDC
1.06
1.01
Program
P&A Eng./AF Comp. Test Data
2.01
Safety Plan
2.01
Engine Installation Handbook
Engine Model Specification
2.01
Reliability Program Plan
Program Status Report
2.01
Reliability Status Report
Human Engineering Plan
2.01
Preliminary Service/ Overhaul Manual
2.01
Maintainability Program Plan
2.01
Outline of Engine Dev. Test Program
2.01
P&A Eng./AF Comp. Test Data
PWA Eng./AF Comp. Test Data
2.01
Issue Calculated PTB Design Weight Report
Engine Operating Instructions
2.01
Update

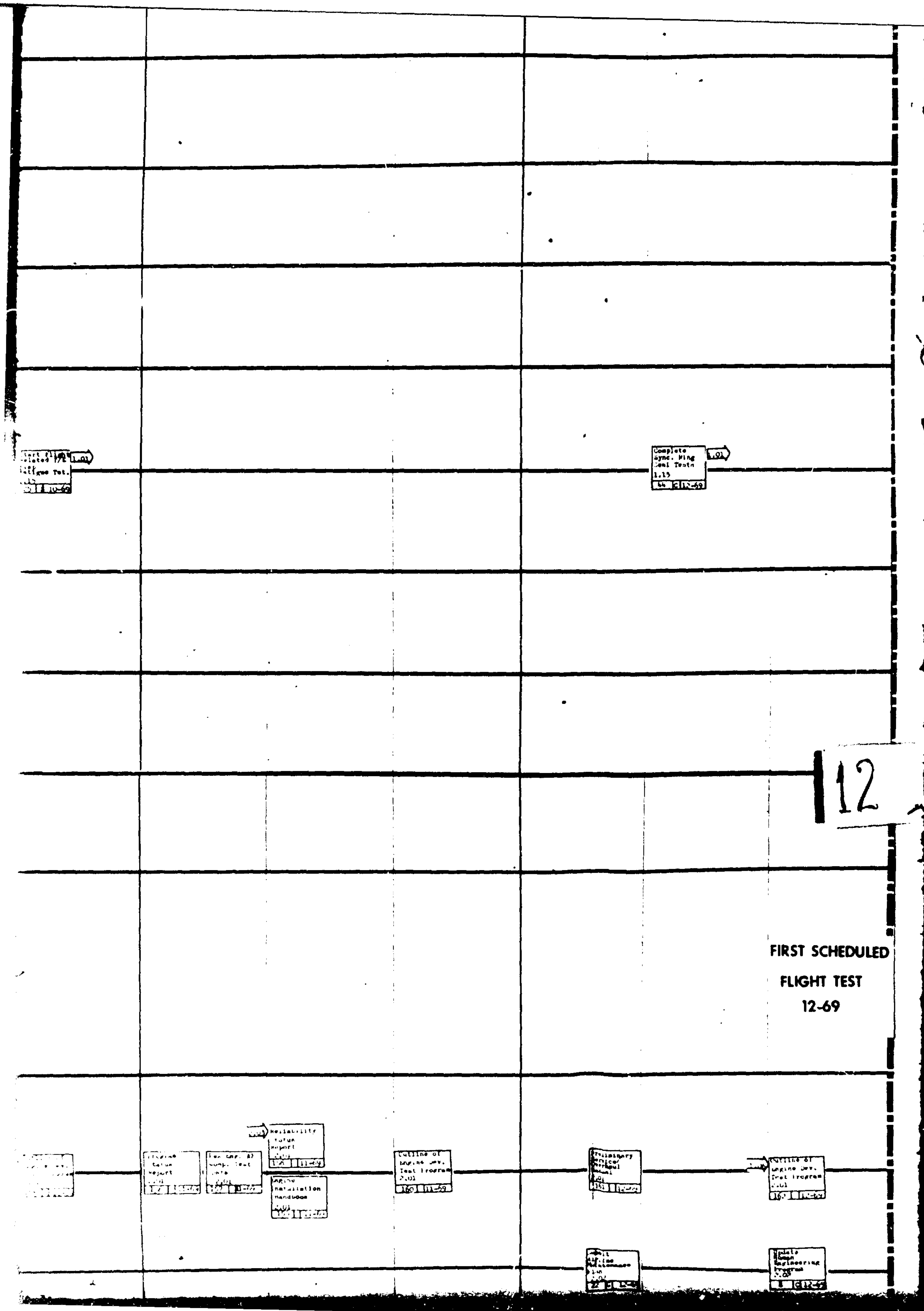

1.01
Complete 75
1.01
1000 Hour
Rig
Completed
1.01
Continue
Advance Sheet
Alloy
Development
1.19
51
4-69
Complete Eval
of Most
Promising
Disk Alloy
1.19
52
1.01
Continue Adv.
Disk Alloy
Development
1.19
53
1.01
Complete
Evaluation of
Alloy 1.19
6-69
1.01
Continue
Blade & Vane
Alloy
Development
1.19
15
weight
Operating
Instructions
2.01
Outline of
Engine Dev.
Test Program
2.01
123
4-69
Program
Status
Report
2.01
124
5-69
P&A Eng./AF
Comp. Test
Data
2.01
125
5-69
Engine
Installation
Handbook
2.01
126
5-69
2.05
Reliability
Status
Report
2.01
127
5-69
1.06
Outline of
Engine Dev.
Test Program
2.01
128
5-69
1.06
Outline of
Engine Dev.
Test Program
2.01
129
6-69
Preliminary
Service/
Overhaul
Manual
2.01
130
6-69
Update Human
Engineering
Program
2.02
7-69
Review
Engine
Maintenance
Manual
2.02
21
6-69



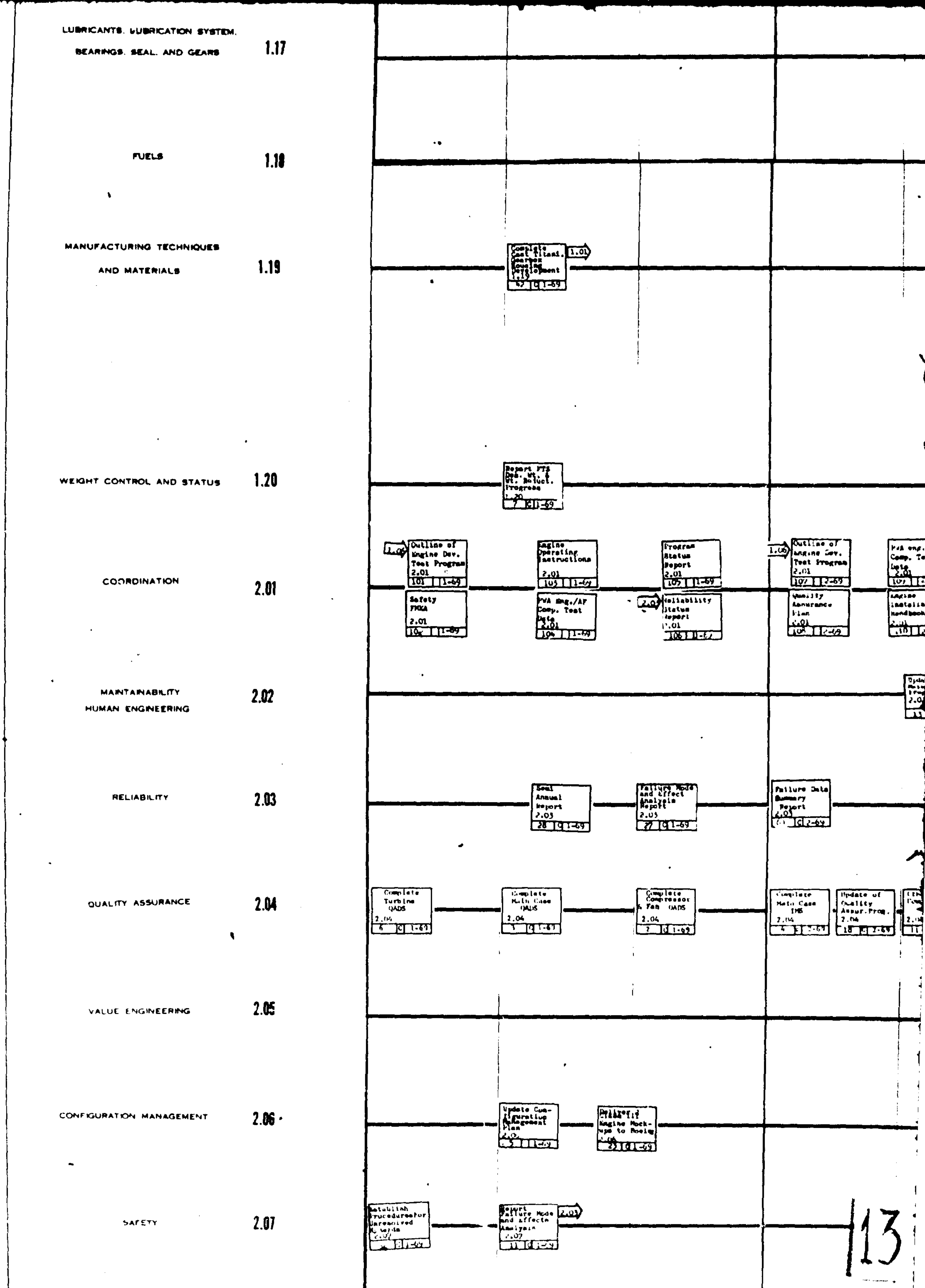
CONTINUE FAN AND COMPRESSOR TESTS IN SUPPORT OF 100 HOURS FLIGHT
CONTINUE PRIMARY COMBUSTOR TESTS IN SUPPORT OF 100 HOUR FLIGHT TEST
CONTINUE TURBINE TESTING IN SUPPORT OF 100 HOURS FLIGHT TEST
CONTINUE AUGMENTOR TESTS IN SUPPORT OF 100 HOUR FLIGHT TEST
CONTINUE EXHAUST SYSTEM TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST
Revise FMEA of Fuel Hyd. and Ignition System 1.164
9 C 7-69
2.01
CONTINUE CONTROL SYSTEMS TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST
CONTINUE FUELS TESTING IN SUPPORT OF 100 HOURS FLIGHT TEST
ENGINE FTS 6-30-69
Compare FTS Dem. Act. Wt. vs Calc. Eng. Wt.
15 C 7-69
Update Calculated Weight FTS Report 1.20
9 C 7-69
Comp. Test Data
Safety FMEA 2.01
7-69
1.06
Outline of Engine Dev. Test Program 2.01
7-69
2.02
Safety Plan 2.01
134 7-69
PMA Eng./AF Comp. Test Data 2.01
7-69
Spare Parts Catalog 2.01
136
2.01
Reliability Status Report 2.01
137 7-69
Engine Operating Instructions 2.01
138 7-69
1.06
Outline of Engine Dev. Test Program 2.01
139 8-69
Eng./AF Compat. Test Data 2.01
140 8-69
Engine Model Specification 2.01
8-69
2.06
Quality Assurance Plan 2.01
142 8-69
Engine Installation Handbook 2.01
8-69
2.03
Reliability Program Plan 2.01
8-69
Update Maintainability Program 2.02
C 8-69



Start Flight
Tests 1.15
10-69
Start Flight
10-69
Start Flight
Fatigue Tst.
1.15
10-69
1.01
Program
Status
Report
Outline of
Engine Dev.
Test Program
Human
Engineering
Plan
Engine
Operating
Instructions
Spare
Parts
Catalog
1.06
Program
Status
Report

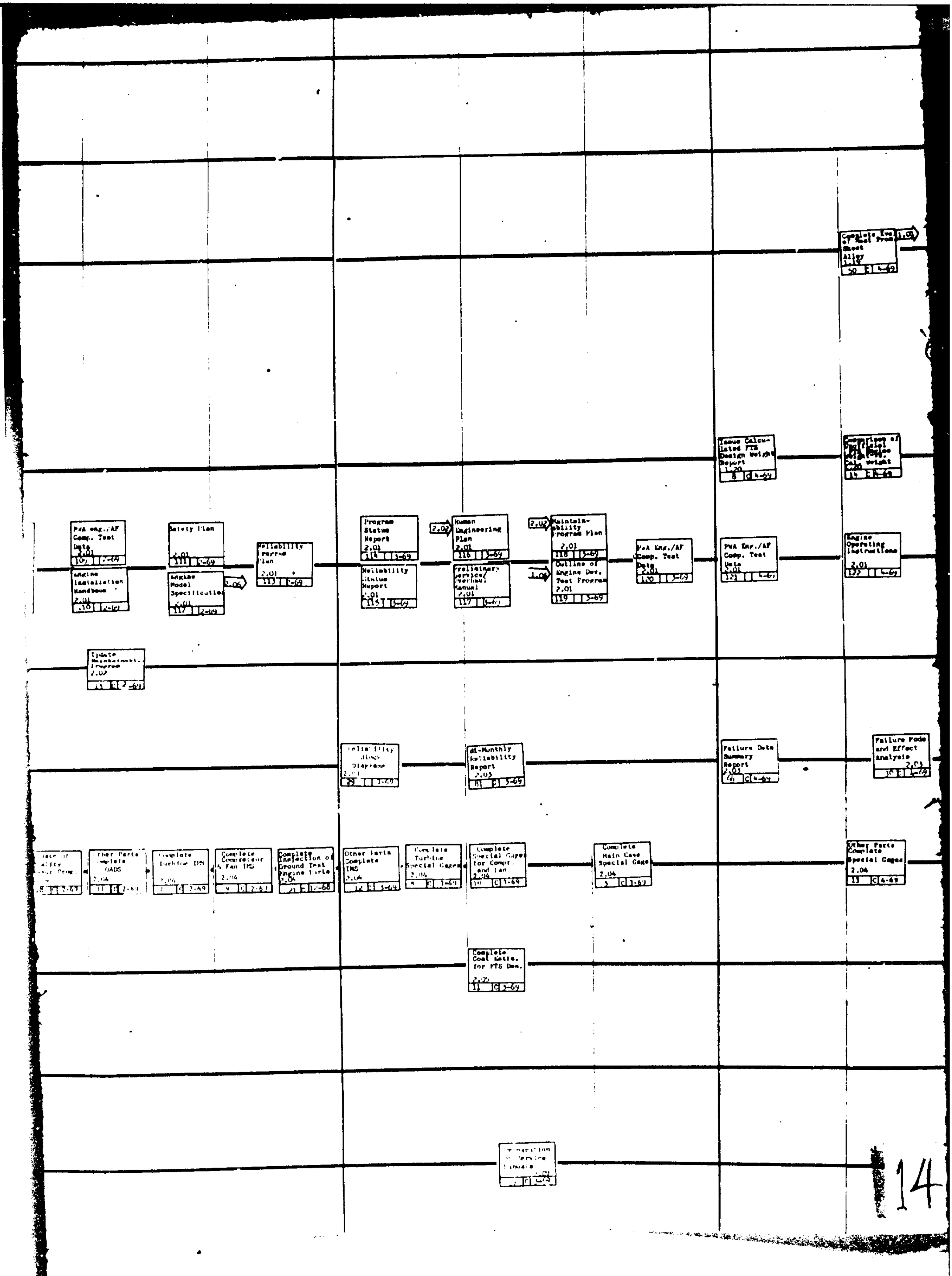


1.01
Complete
Sync. Wing
Semi Tests
1.15
64 C 12-69
1.01
12
FIRST SCHEDULED
FLIGHT TEST
12-69
Reliability
Report
Outline of
Engine Dev.
Test Program
2.01
160 11-69
Installation
Handbook
Outline of
Engine Dev.
Test Program
Engineering
Program
8 C 12-69



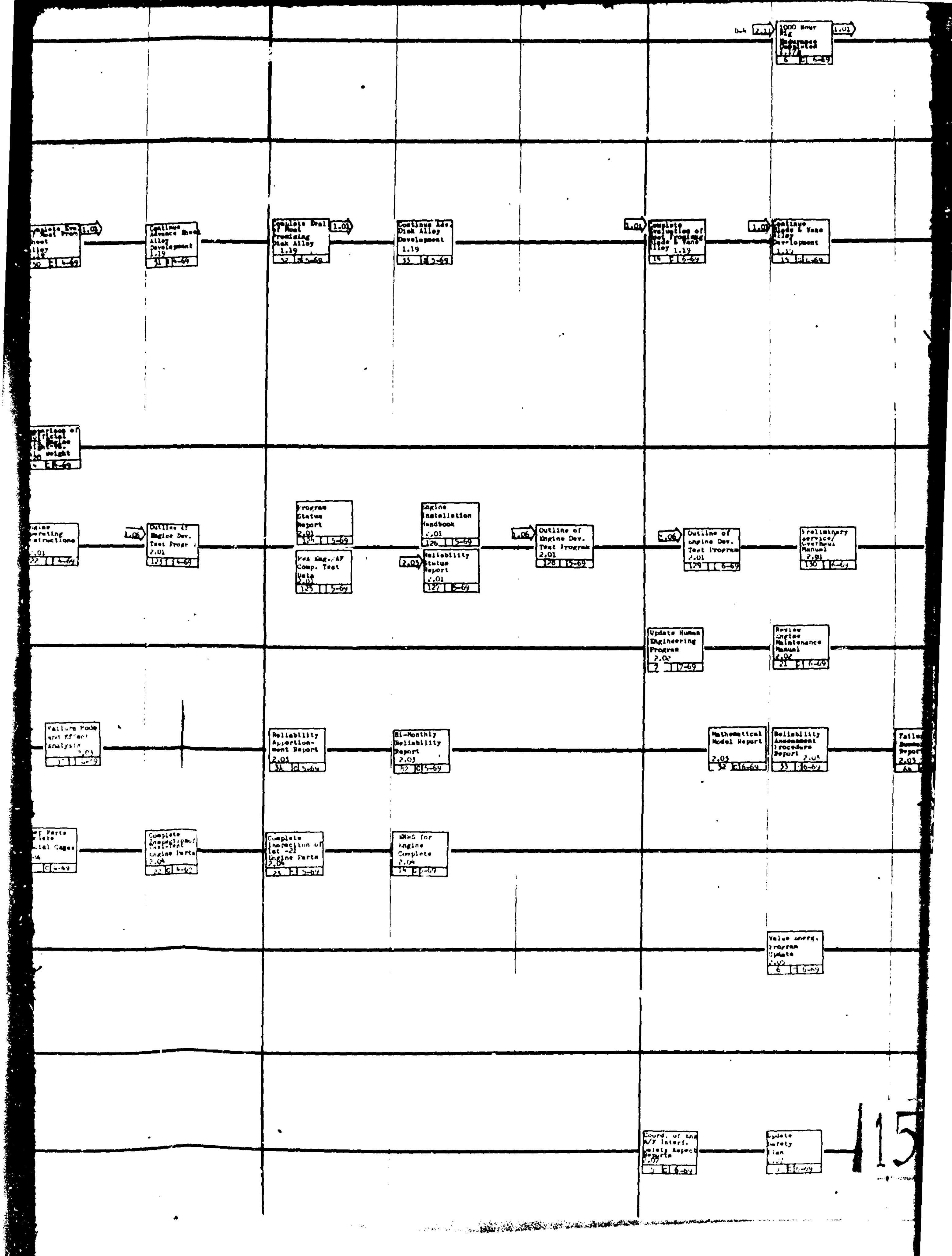
LUBRICANTS, LUBRICATION SYSTEM, BEARINGS, SEAL, AND GEARS
1.17
FUELS
1.18
MANUFACTURING TECHNIQUES AND MATERIALS
1.19
Gearbox Housing Development
1.01
WEIGHT CONTROL AND STATUS
1.20
Report PTS
Progress
7 C 1-69
COORDINATION
2.01
Outline of Engine Dev. Test Program 2.01
101 1-69
Safety FMEA 2.01
1-69
Engine Operating Instructions 2.01
1-69
PWA Eng./AF Comp. Test Data 2.01
1-69
Program Status Report 2.01
1-69
Reliability Status Report
Outline of Engine Dev. Test Program 2.01
2-69
Quality Assurance Plan
2-69
MAINTAINABILITY HUMAN ENGINEERING
2.02
RELIABILITY
2.03
Semi Annual Report 2.03
28 C 1-69
Failure Mode and Effect Analysis Report 2.03
27 C 1-69
Failure Data Summary Report
C 2-69
QUALITY ASSURANCE
2.04
Complete Turbine QADS 2.04
6 C 1-69
Complete Main Case QADS 2.04
Complete Compressor & Fan QADS 2.04
Complete Main Case IMS 2.04
Update of Quality Assur. Prog. 2.04
18 C 2-69
VALUE ENGINEERING
2.05
CONFIGURATION MANAGEMENT
2.06
Update Configuration Management Plan
Engine Mock-ups to Boeing
SAFETY
2.07
Establish Procedures for Unresolved
Report Failure Mode and Effects Analysis
2.03
2.07
11 C 1-69

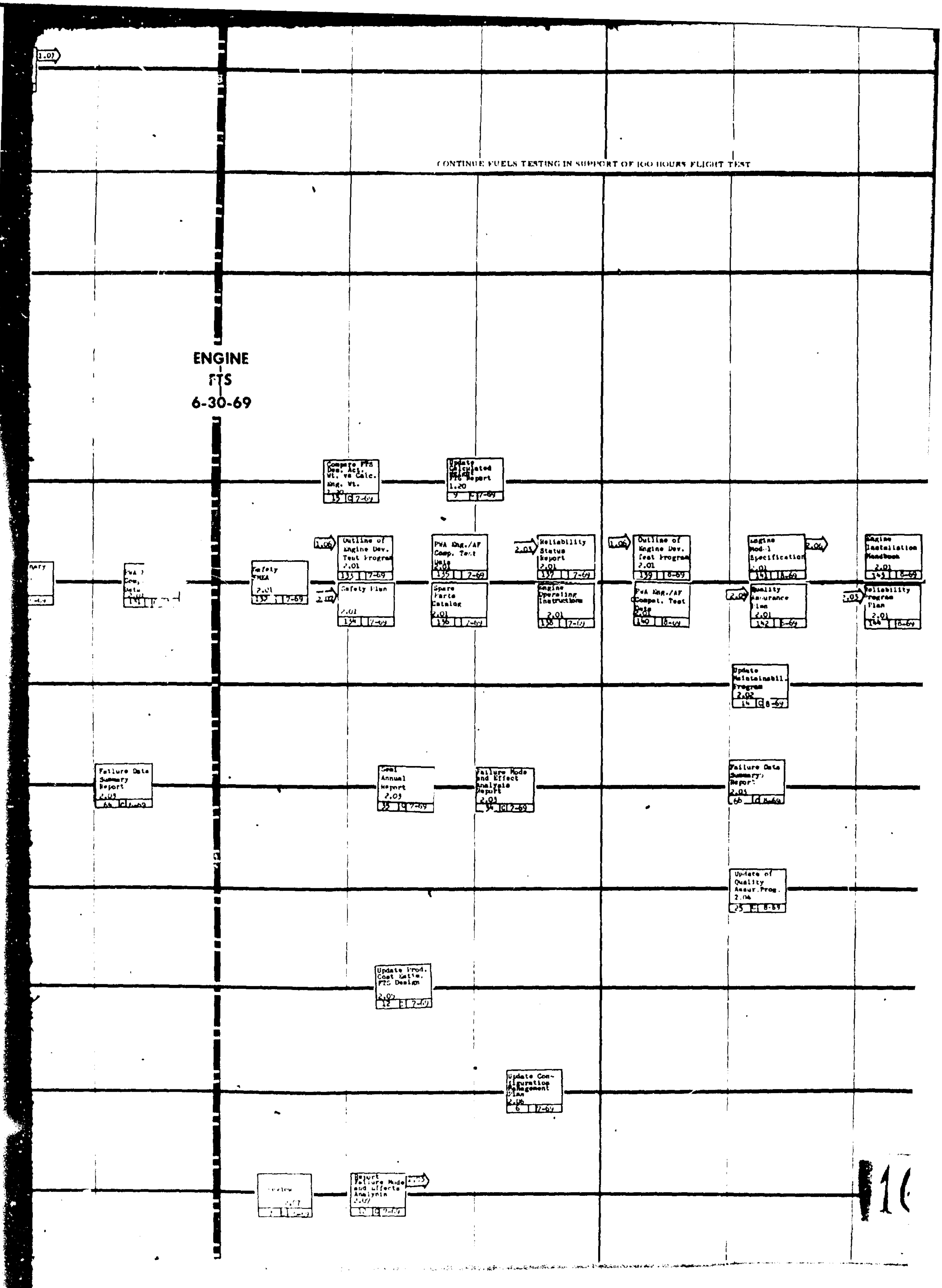
13

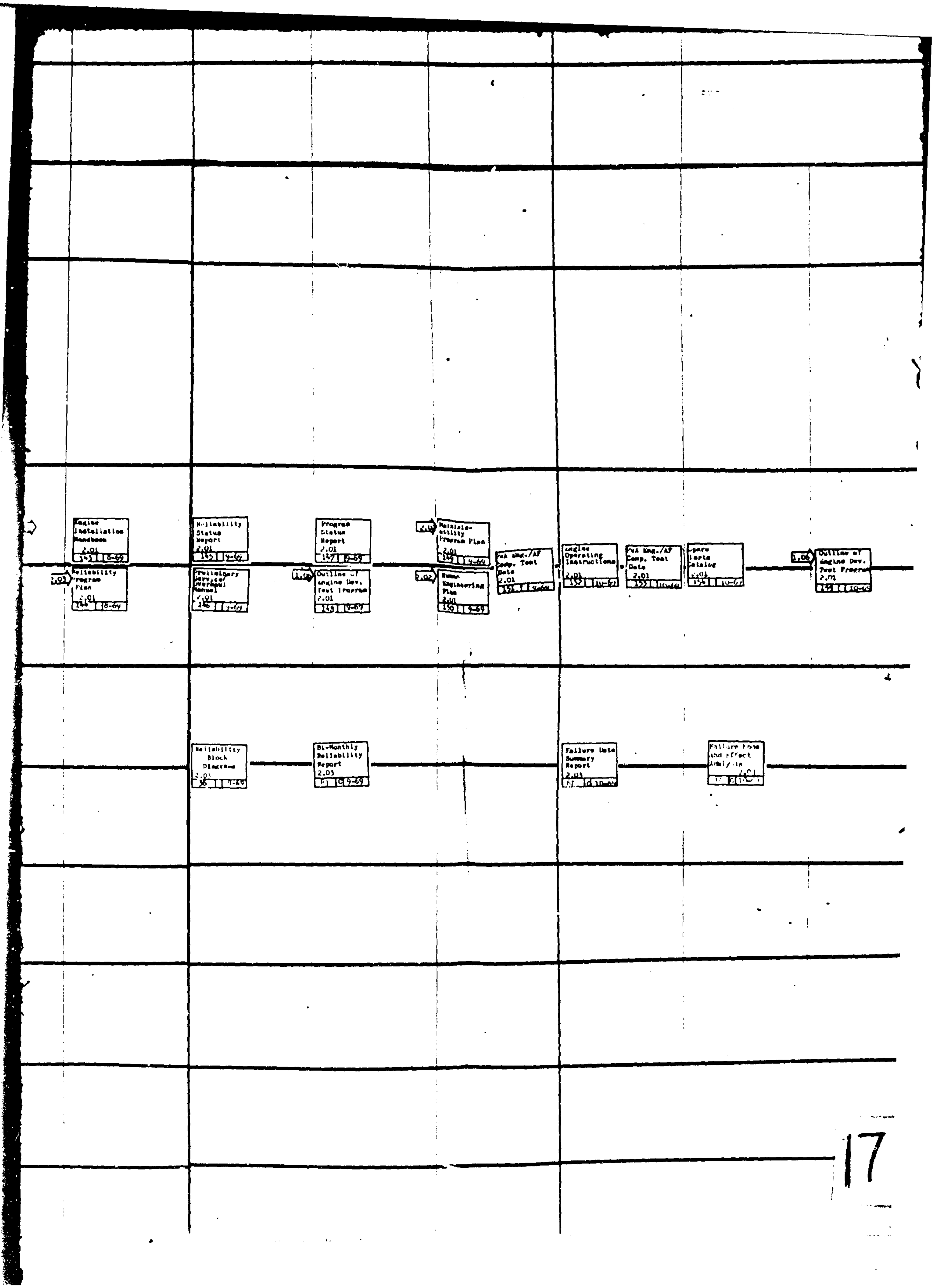


Complete Eval of Cast Prem Sheet Alloy 1.19
Issue Calculated FTS Design Weight Report 1.20
Comparison of Official Engine Weight vs. Calc. Weight
P&A Eng./AF Comp. Test Data 2.01
Engine Installation Handbook 2.01
Safety Plan 2.01
Engine Model Specification 2.01
Reliability Program Plan 2.01
Program Status Report 2.01
Reliability Status Report 2.01
Human Engineering Plan 2.01
Preliminary Service/Overhaul Manual 2.01
Maintainability Program Plan 2.01
Outline of Engine Dev. Test Program 2.01
P&A Eng./AF Comp. Test Data 2.01
P&A Eng./AF Comp. Test Data 2.01
Engine Operating Instructions 2.01
Update Maintainability Program 2.02
Reliability Block Diagrams
Bi-Monthly Reliability Report 2.03
Failure Data Summary Report 2.03
Failure Mode and Effect Analysis 2.03
Other Parts Complete GADS 2.04
Complete Turbine TMS
Complete Compressor & Fan TMS 2.04
Complete Inspection of Ground Test Engine Parts 2.04
Other Parts Complete TMS 2.04
Complete Turbine Special Gages 2.04
Complete Special Gages for Compr. and Fan 2.04
Complete Main Case Special Gages 2.04
Other Parts Complete Special Gages 2.04
Complete Coat Estim. for FTS Dev.

14

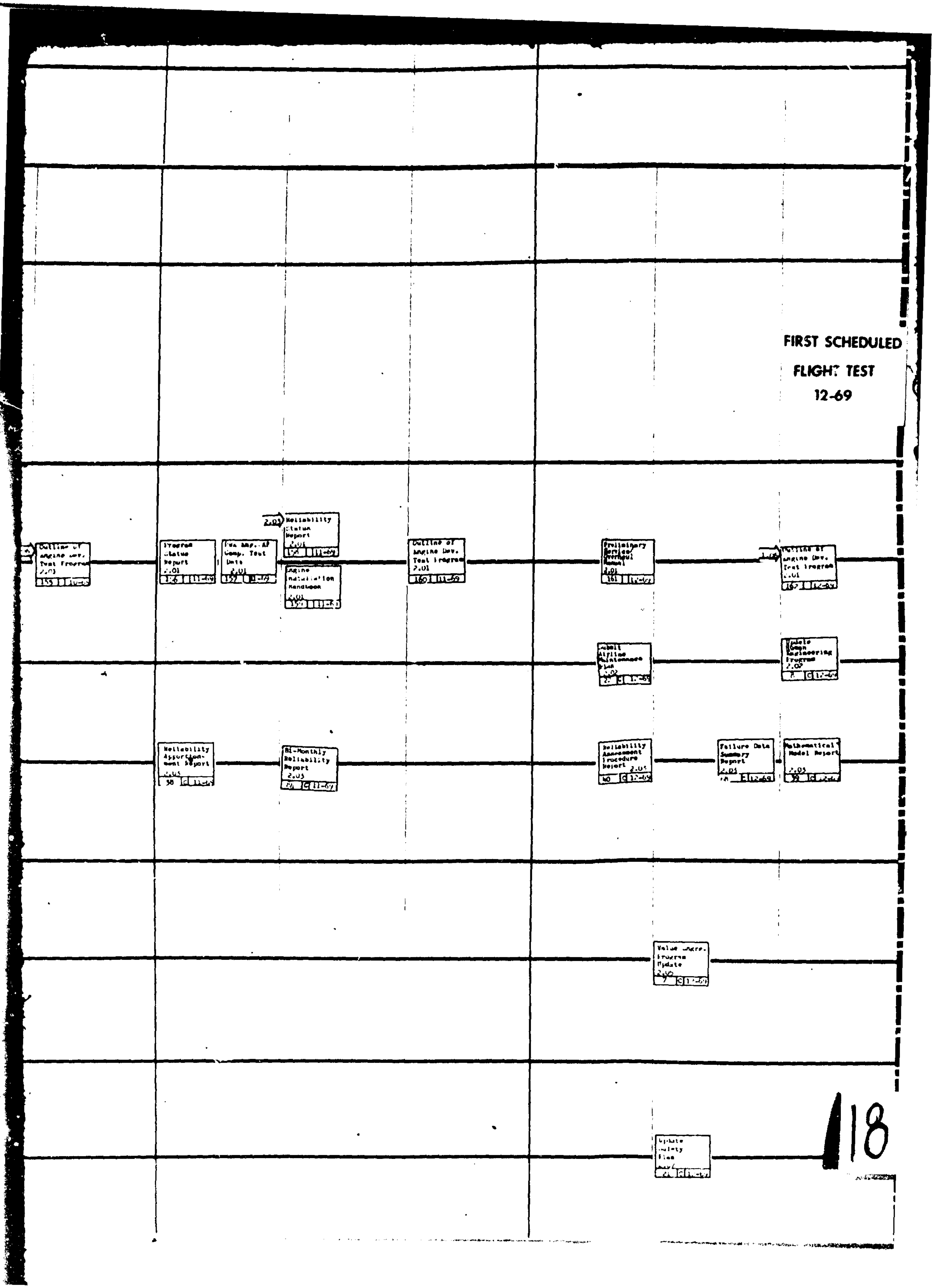

1000 Hour
Continue Advance Sheet Alloy Development 1.19
Complete Eval of Most Promising Disk Alloy 1.19
Continue Adv. Disk Alloy Development 1.19
Continue Blade & Vane Alloy Development
Program Status Report 2.01
Engine Installation Handbook 2.01
P&A Eng./AF Comp. Test Data 2.01
Reliability Status Report 2.01
Outline of Engine Dev. Test Program 2.01
Preliminary Service/ Overhaul Manual 2.01
Update Human Engineering Program 2.02
Review Engine Maintenance Manual 2.02
Failure Mode and Effect Analysis
Reliability Apportionment Report 2.03
Bi-Monthly Reliability Report 2.03
Mathematical Model Report 2.03
Reliability Assessment Procedure Report 2.03
Complete Inspection of Engine Parts 2.04
Value Engrg. Program Update
Coord. of the A/F Interf. Safety Aspect Reports
Update Safety Plan
15


CONTINUE FUELS TESTING IN SUPPORT OF 100 HOURS FLIGHT TEST
ENGINE
FTS
6-30-69
Compare FTS Des. Act. Wt. vs Calc. Eng. Wt.
Update Calculated Weight Pro Report 1.20
Outline of Engine Dev. Test Program 2.01
PWA Eng./AF Comp. Test Data 2.01
Reliability Status Report 2.01
Outline of Engine Dev. Test Program 2.01
Engine Model Specification 2.01
Engine Installation Handbook 2.01
Safety FMEA 2.01
Safety Plan 2.01
Spare Parts Catalog 2.01
Engine Operating Instructions 2.01
PWA Eng./AF Compat. Test Data 2.01
Quality Assurance Plan 2.01
Reliability Program Plan 2.01
Update Maintainability Program 2.02
Failure Data Summary Report 2.03
Semi Annual Report 2.03
Failure Mode and Effect Analysis Report 2.03
Failure Data Summary Report 2.03
Update of Quality Assur. Prog. 2.04
Update Prod. Cost Estim. FTS Design 2.05
Update Configuration Management Plan 2.06
Report Failure Mode and Effects Analysis 2.07



Engine Installation Handbook 2.01
143 8-69
2.03
Reliability Program Plan 2.01
144 8-69
Reliability Status Report 2.01
145 9-69
Preliminary Service/Overhaul Manual 2.01
146 9-69
Program Status Report 2.01
147 9-69
1.06
Outline of Engine Dev. Test Program 2.01
9-69
Maintainability Program Plan 2.01
149 9-69
2.02
Human Engineering Plan 2.01
150 9-69
FAA Eng./AF Comp. Test Data 2.01
Engine Operating Instructions 2.01
10-69
FAA Eng./AF Comp. Test Data 2.01
Spare Parts Catalog
1.06
Outline of Engine Dev. Test Program 2.01
Reliability Block Diagrams
9-69
Bi-Monthly Reliability Report 2.03
9-69
Failure Data Summary Report
10-69
Failure Mode and Effect Analysis

17


FIRST SCHEDULED
FLIGHT TEST
12-69
Reliability Status Report
Bi-Monthly Reliability Report
Mathematical Model Report
Failure Data Summary Report
Value Engrg. Program Update

18

PHASE III WORK BREAKDOWN JTF17		1970 TEST PLANNING AND INTEGRATION JAN	F
ENGINE DESIGN	1.01		
FABRICATION AND ASSEMBLY	1.02		
ENGINE INSTRUMENTATION	1.04		
TEST EQUIPMENT	1.05		
FACILITIES	2.11		
ENGINE TEST - GROUND	1.06		
ENGINE PERFORMANCE	1.07	Model and Perform. Spec. 1.07 25 d 1-30 → 2.06	
INLET SYSTEM COMPATIBILITY	1.08		
NOISE	1.09		
FAN AND COMPRESSOR	1.11		
PRIMARY COMBUSTOR	1.12		
TURBINE	1.13		

2

FEB			MAR			AP
						CONTINUE DESIGN SUPPORT OF 10[illegible] HOUR
						CONTINUE ENGINE TESTS IN SUPPORT
						CONTINUE ENGINE PERFORMANCE EVALUA
						CONTINUE INLET SYSTEM COMPATIBILI
						CONTINUE NOISE TESTS IN SUPPORT O
						CONTINUE FAN AND COMPRESSOR TESTS
						CONTINUE PRIMARY COMBUSTOR TESTS
						CONTINUE TURBINE TESTING IN SUPPORT

TEST PLANN

3

	APR			MAY			
N SUPPORT OF 100 HOURS FLIGHT TEST							
NE TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST							
ERFORMANCE EVALUATIONS IN SUPPORT OF 100 HOUR FLIGHT TEST							
SYSTEM COMPATIBILITY TESTS IN SUPPORT OF 100 HOURS							
TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST							
COMPRESSOR TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST							
COMBUSTOR TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST							
TESTING IN SUPPORT OF 100 HOUR FLIGHT TEST							

NNING AND INTEGRATION

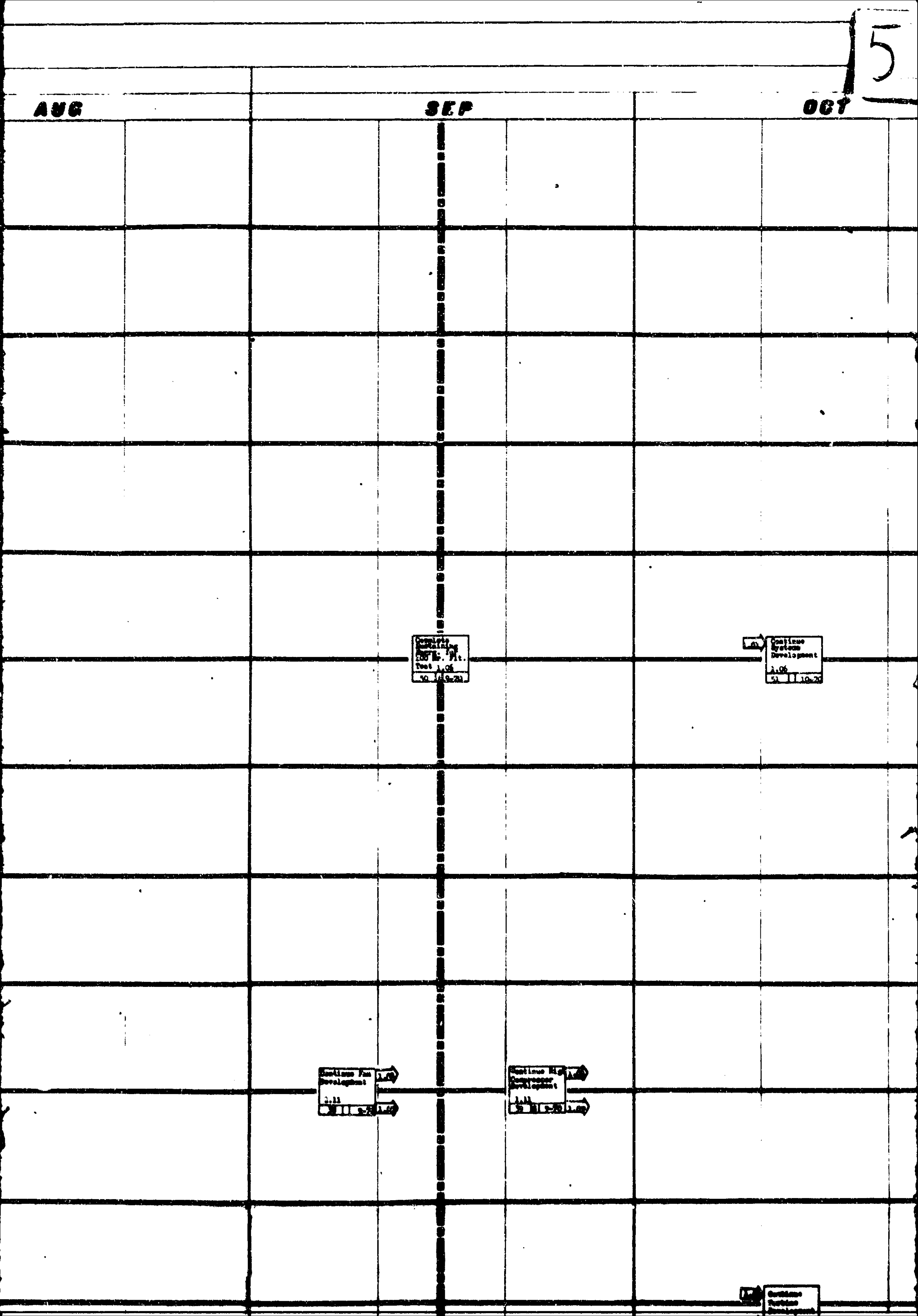
1970

4

JUN		JUL			AUG	

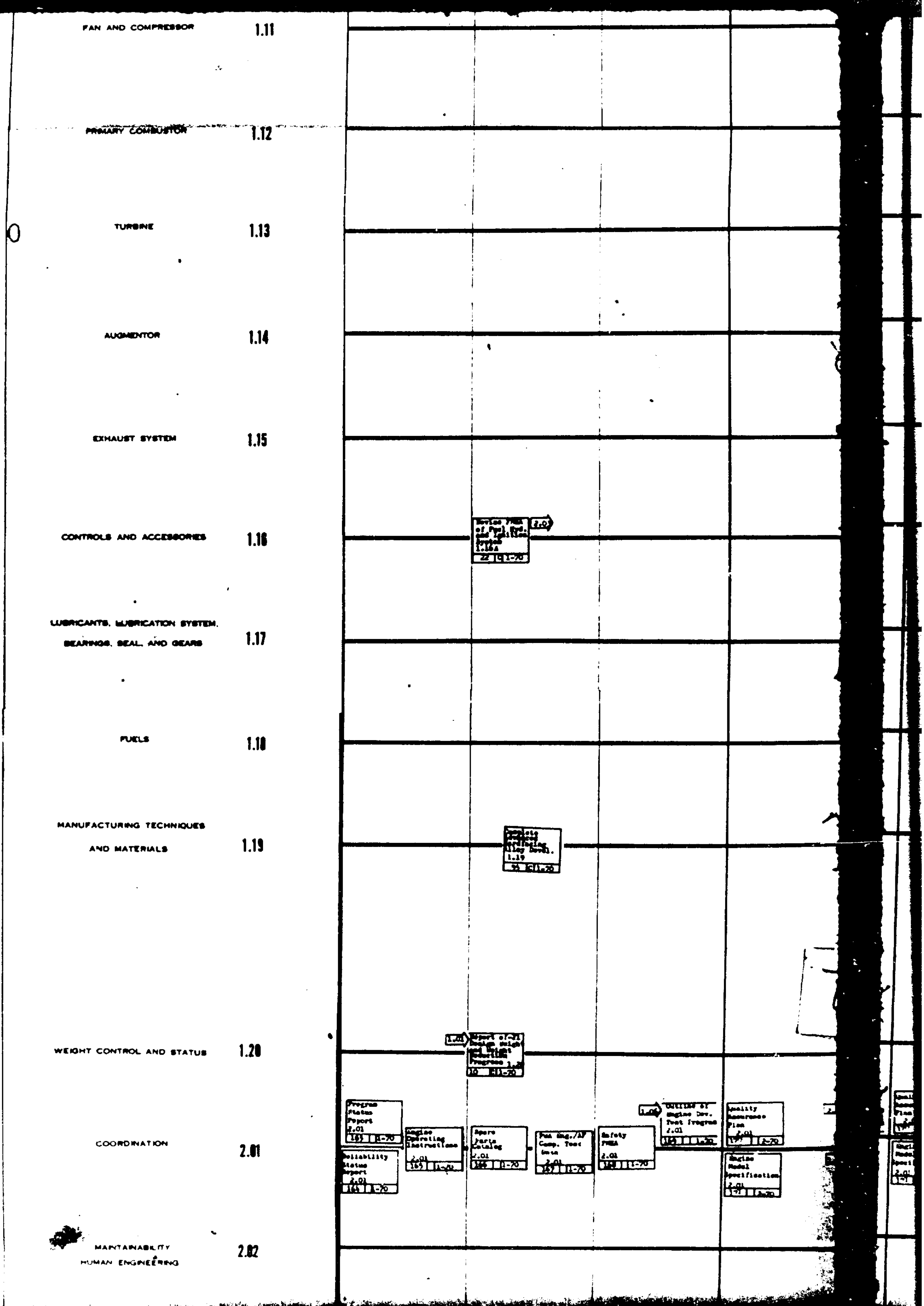
Model and Perform. Spec.

7-70

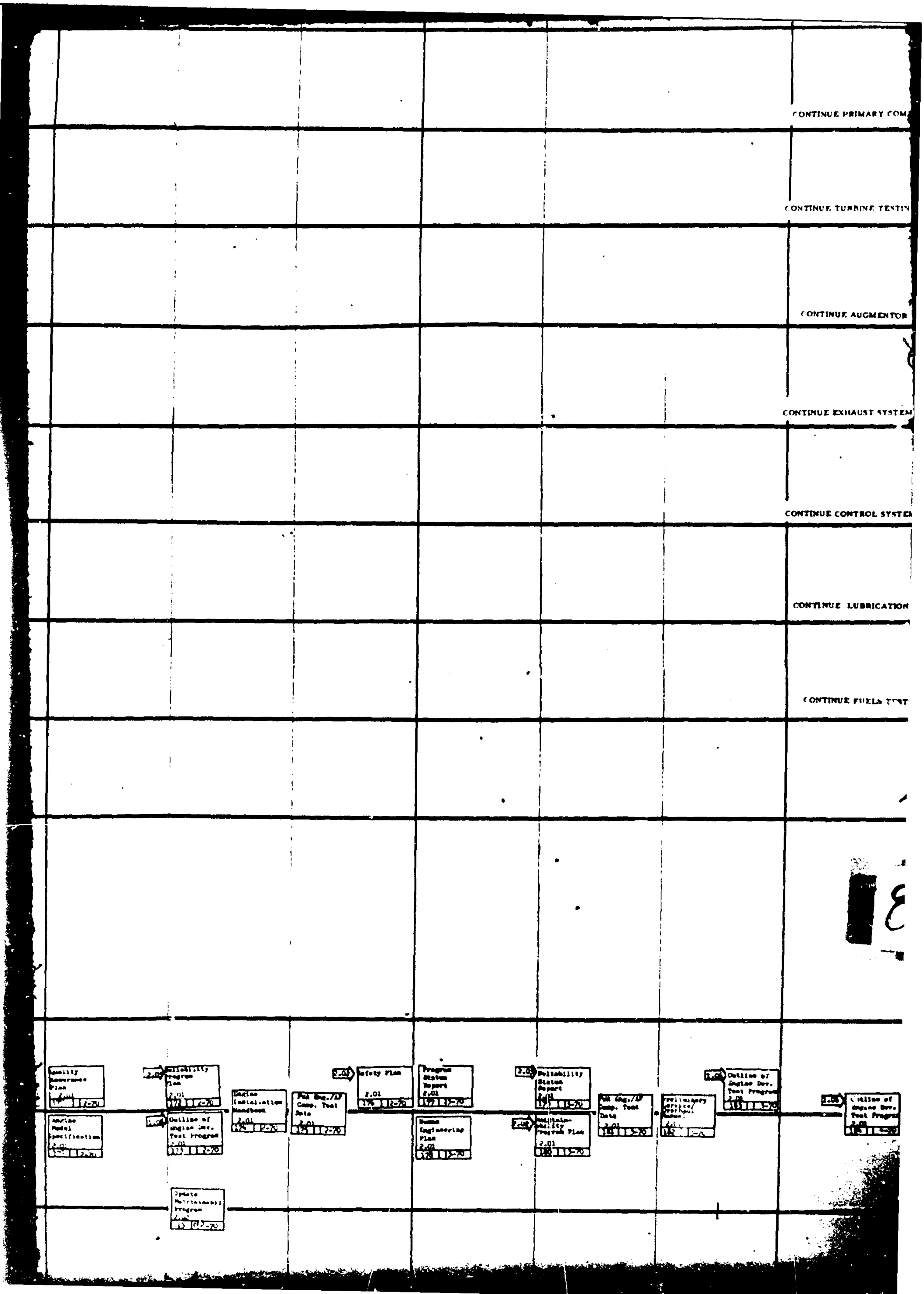

5
AUG
SEP
OCT
Complete
Test 1.06
50
Continue
System
Development
1.06
51
Continue Fan
Development
1.11
Continue High
Compressor
Development
1.11
Continue
System
Development

6

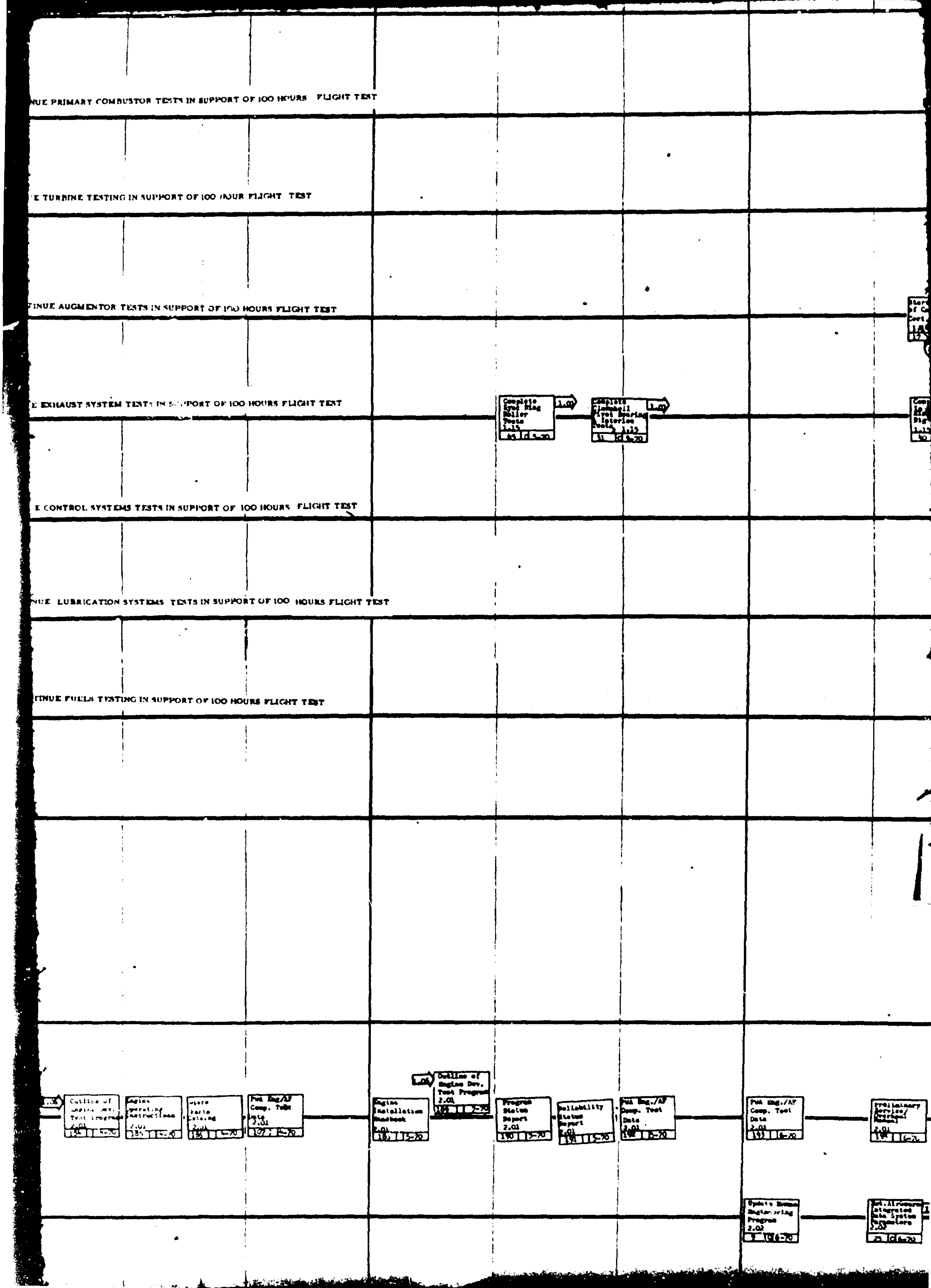
		NOV			DEC	

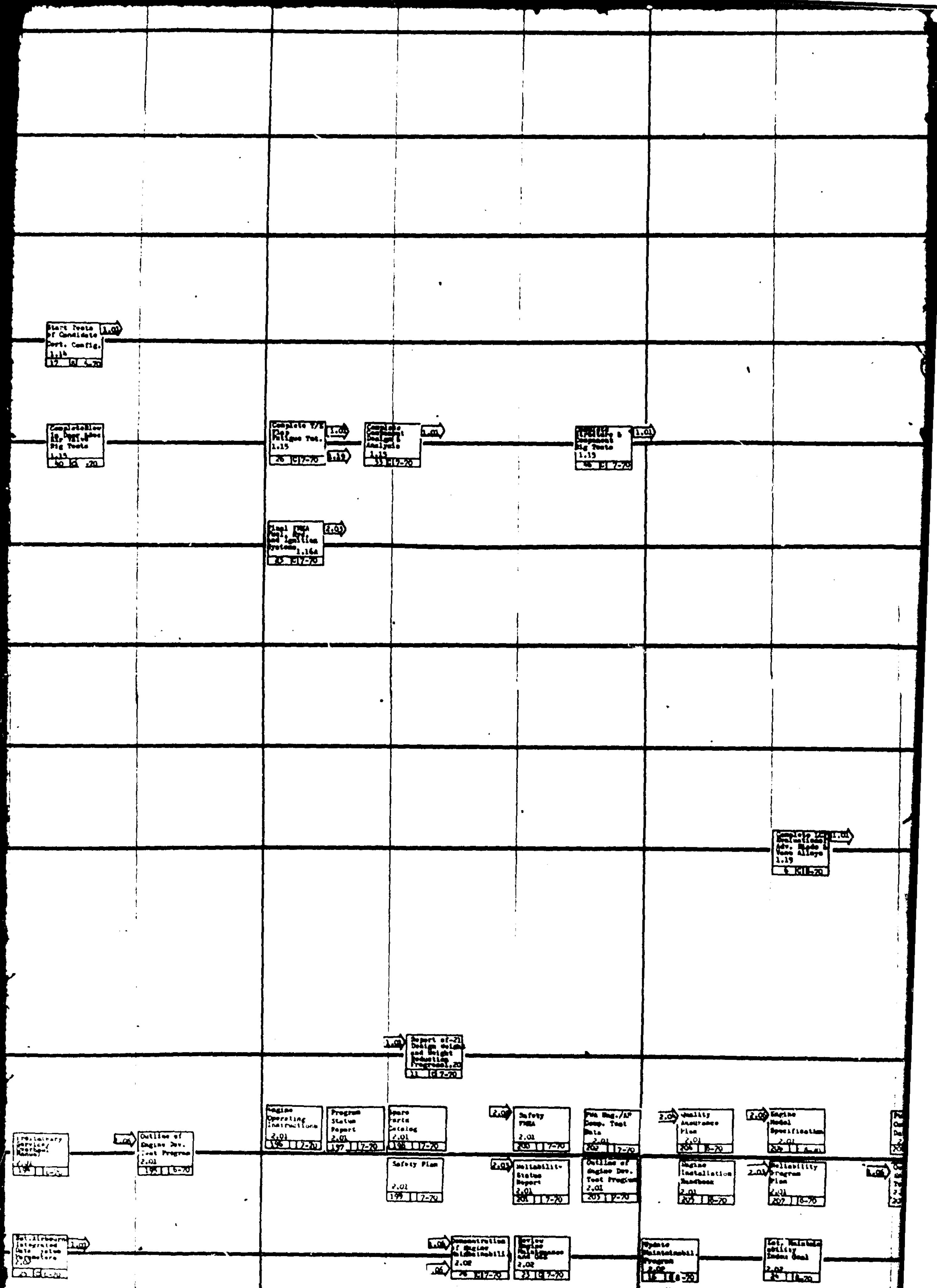


FAN AND COMPRESSOR
1.11
PRIMARY COMBUSTOR
1.12
TURBINE
1.13
AUGMENTOR
1.14
EXHAUST SYSTEM
1.15
CONTROLS AND ACCESSORIES
1.16
LUBRICANTS, LUBRICATION SYSTEM, BEARINGS, SEAL, AND GEARS
1.17
FUELS
1.18
MANUFACTURING TECHNIQUES AND MATERIALS
1.19
WEIGHT CONTROL AND STATUS
1.20
COORDINATION
2.01
MAINTAINABILITY HUMAN ENGINEERING
2.02
Program Status Report 2.01
Reliability Status Report 2.01
Engine Operating Instructions 2.01
Spare Parts Catalog 2.01
Safety FMEA 2.01
Quality Assurance Plan 2.01
Engine Model Specification 2.01

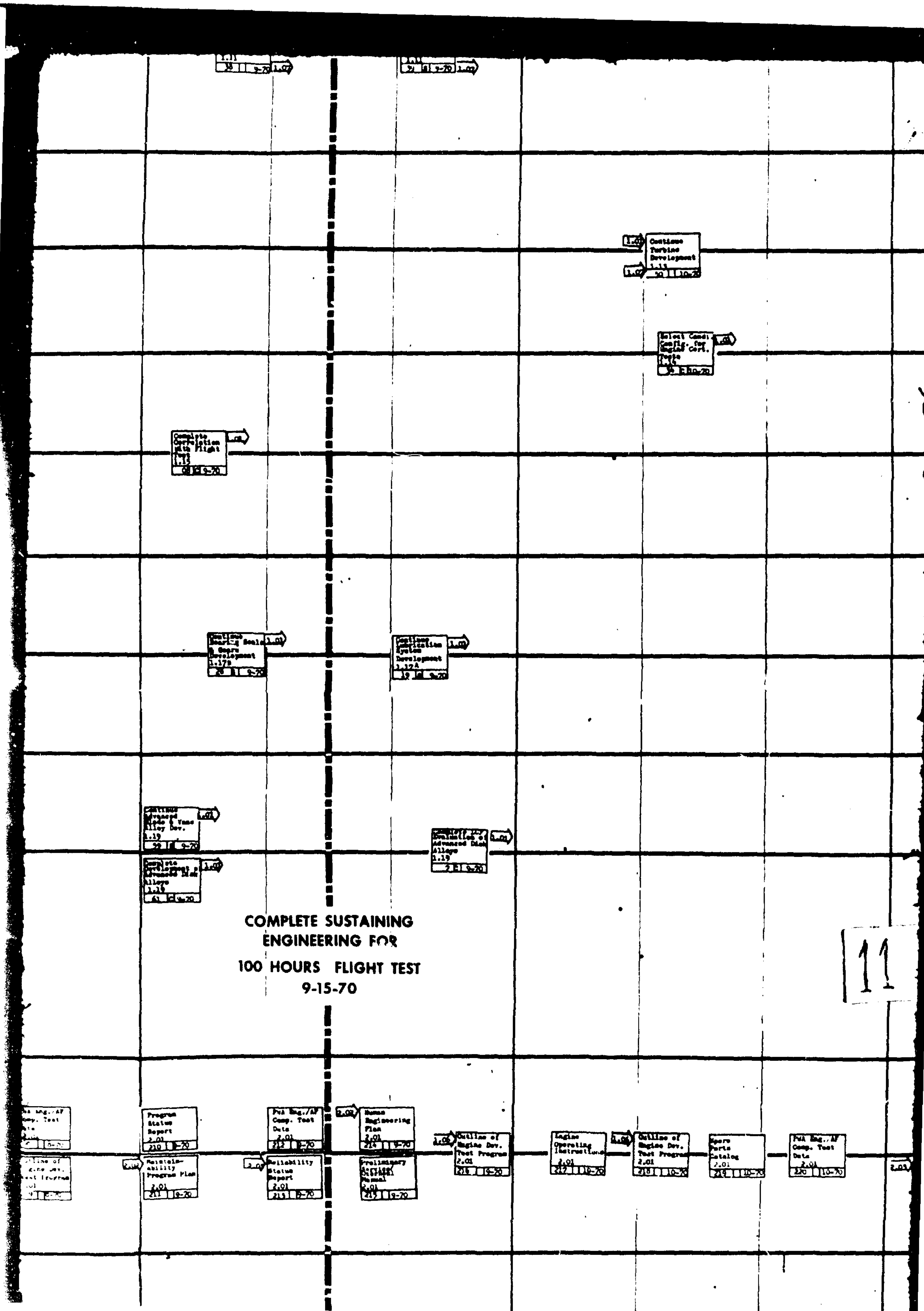


CONTINUE PRIMARY COM
CONTINUE TURBINE TESTIN
CONTINUE AUGMENTOR
CONTINUE EXHAUST SYSTEM
CONTINUE CONTROL SYSTEM
CONTINUE LUBRICATION
CONTINUE FUELS TEST
Quality Assurance Plan
Engine Model Specification
Reliability Program Plan
2.01
Outline of Engine Dev. Test Program
2.01
Update Maintainability Program
Engine Installation Handbook
2.01
Comp. Test Data
2.01
Safety Plan
2.01
Program Status Report
2.01
Human Engineering Plan
2.01
Reliability Status Report
2.01
Maintainability Program Plan
2.01
Comp. Test Data
2.01
Outline of Engine Dev. Test Program
Outline of Engine Dev. Test Program

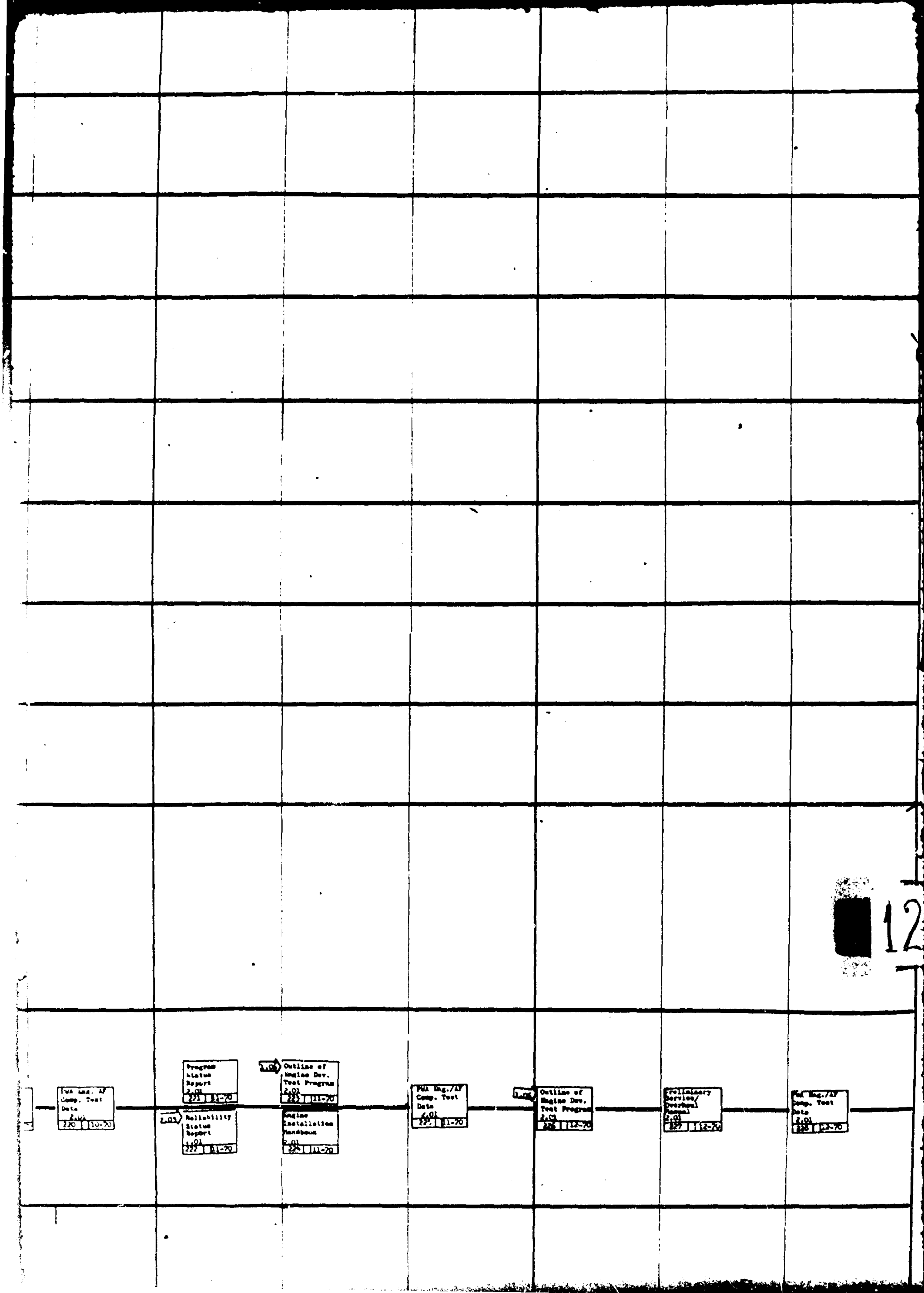

NUE PRIMARY COMBUSTOR TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST
E TURBINE TESTING IN SUPPORT OF 100 HOUR FLIGHT TEST
TINUE AUGMENTOR TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST
E EXHAUST SYSTEM TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST
Complete
Roller
1.15
1.01
Interior
1.15
1.01
E CONTROL SYSTEMS TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST
NUE LUBRICATION SYSTEMS TESTS IN SUPPORT OF 100 HOURS FLIGHT TEST
TINUE FUELS TESTING IN SUPPORT OF 100 HOURS FLIGHT TEST
Outline of
Test Program
2.01
Engine
Operating
Instructions
2.01
Parts
Catalog
2.01
Comp. Test
Data
2.01
Engine
Installation
Handbook
2.01
Outline of
Engine Dev.
Test Program
2.01
Program
Status
Report
2.01
190
5-70
Reliability
Status
Report
2.01
Comp. Test
Data
2.01
Comp. Test
Data
2.01
Preliminary
Service/
2.01
Update
Engineering
Program
2.02
Integrated
Data System
Parameters
25



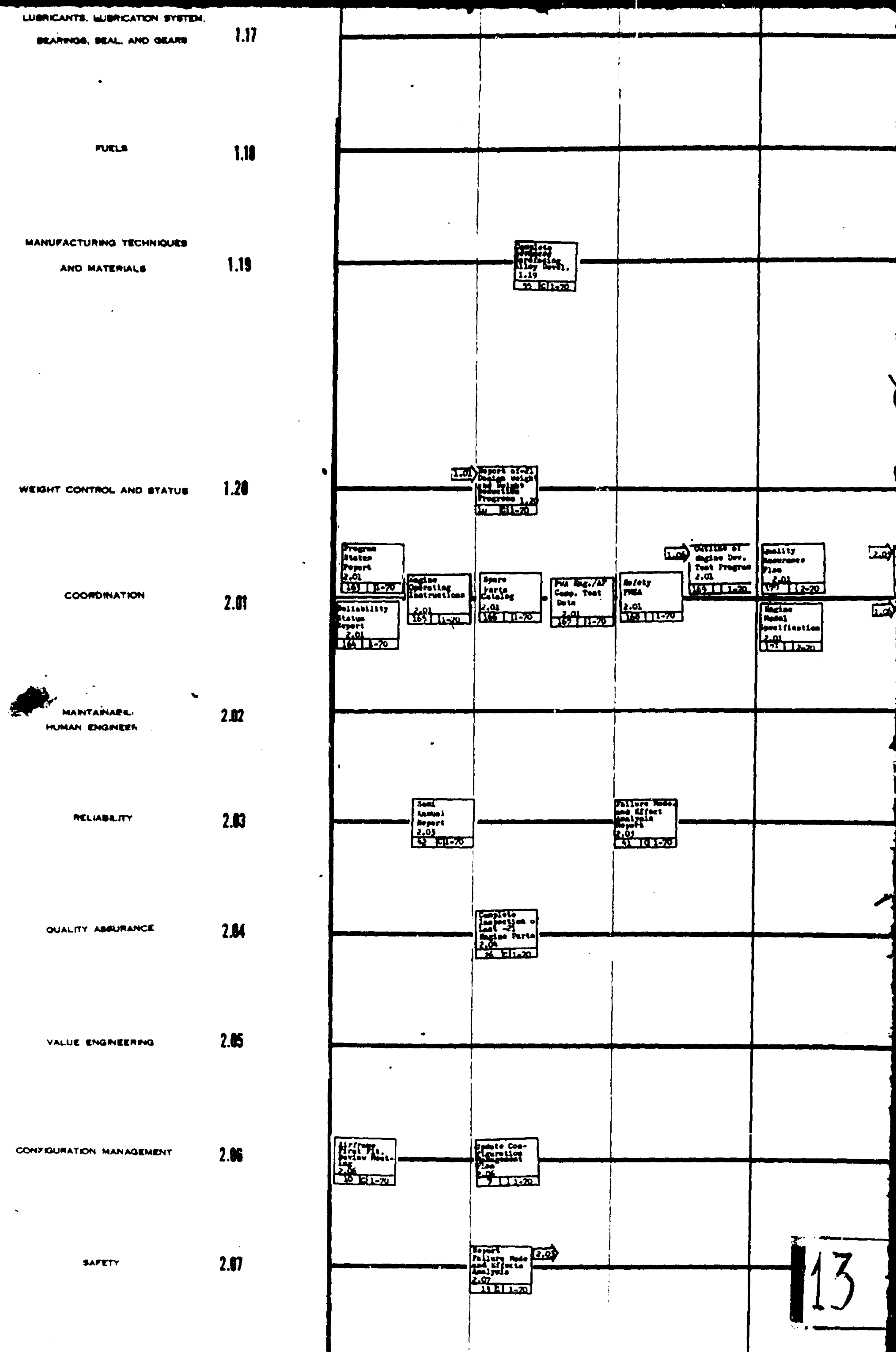
Start Tests of Candidate Conf. Config.
Complete T/S Fatigue Test
1.15
Final FMEA
Report of -21 Design Weight and Weight Reduction Program
Outline of Engine Dev. Test Program
2.01
Engine Operating Instructions
2.01
Program Status Report
2.01
Spare Parts Catalog
2.01
Safety Plan
2.01
Safety FMEA
2.01
Reliability Status Report
2.01
Outline of Engine Dev. Test Program
2.01
Quality Assurance Plan
2.01
Engine Model Specification
2.01
Engine Installation Handbook
2.01
Reliability Program Plan
2.01
Update Maintainability Program
2.02


COMPLETE SUSTAINING
ENGINEERING FOR
100 HOURS FLIGHT TEST
9-15-70

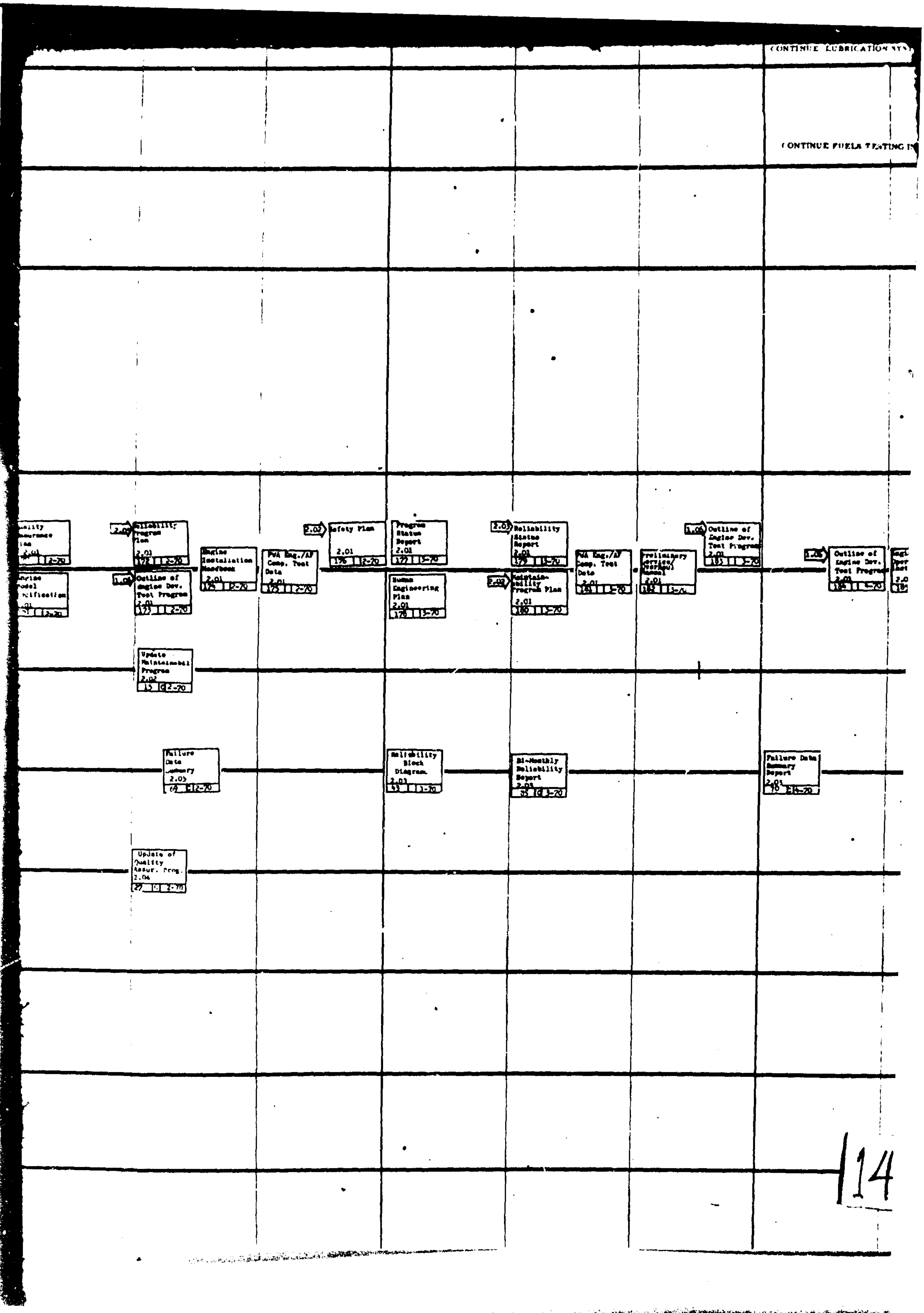
11



PWA Eng. AF Comp. Test Data 2.01 220 10-70
Program Status Report 2.01 221 11-70
2.05
Reliability Status Report 1.01 222 11-70
Outline of Engine Dev. Test Program 2.01 223 11-70
Engine Installation Handbook 2.01 224 11-70
PWA Eng./AF Comp. Test Data 2.01 225 11-70
Outline of Engine Dev. Test Program 2.01 226 12-70
Preliminary Service/ Overhaul Manual 2.01 227 12-70
PWA Eng./AF Comp. Test Data 2.01 228 12-70
12

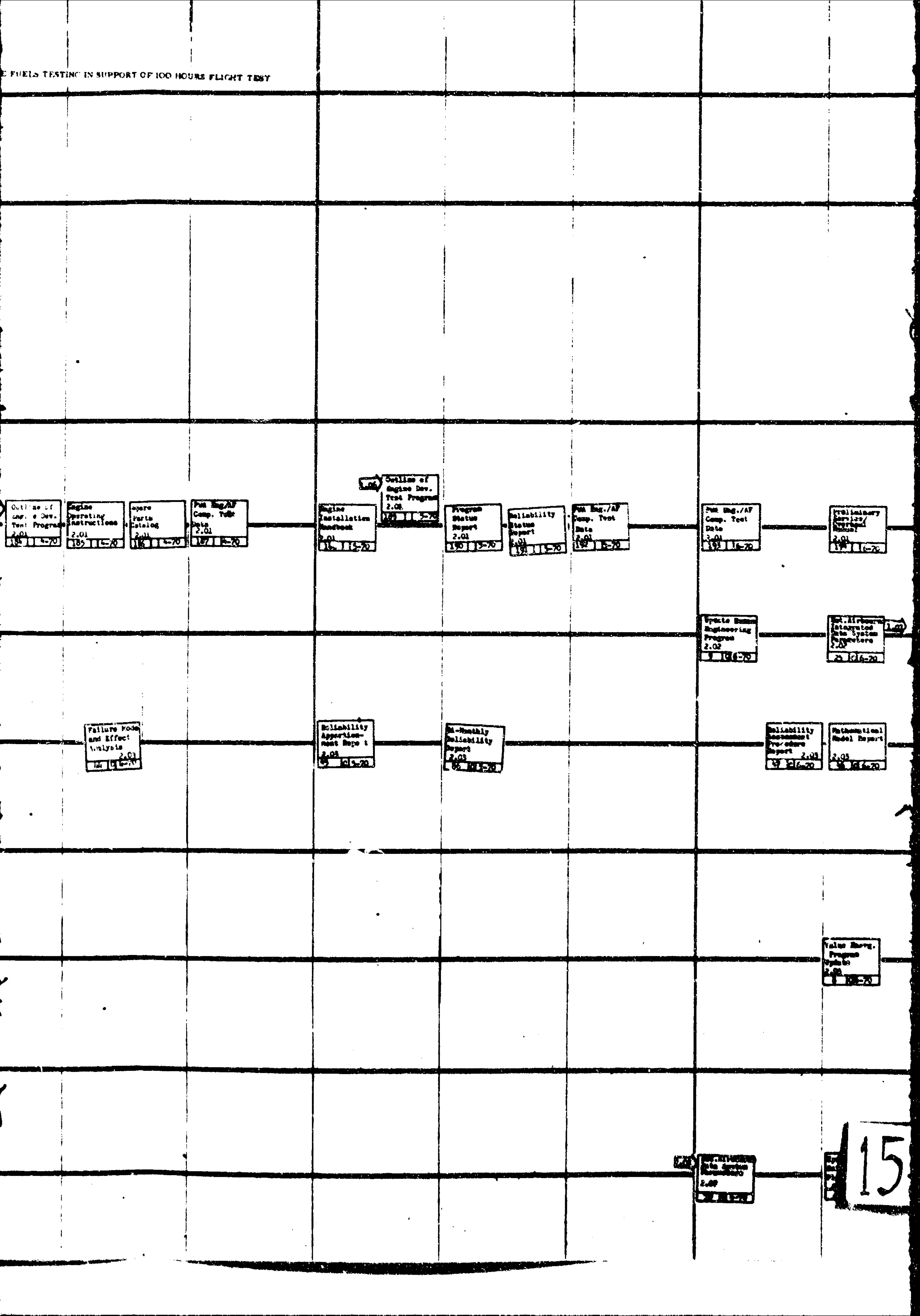


LUBRICANTS, LUBRICATION SYSTEM, BEARINGS, SEAL, AND GEARS 1.17
FUELS 1.18
MANUFACTURING TECHNIQUES AND MATERIALS 1.19
WEIGHT CONTROL AND STATUS 1.20
COORDINATION 2.01
MAINTAINABIL. HUMAN ENGINEER 2.02
RELIABILITY 2.03
QUALITY ASSURANCE 2.04
VALUE ENGINEERING 2.05
CONFIGURATION MANAGEMENT 2.06
SAFETY 2.07
Program Status Report 2.01
Reliability Status Report 2.01
Engine Operating Instructions 2.01
Spare Parts Catalog 2.01
Safety FMEA 2.01
Quality Assurance Plan 2.01
Engine Model Specification 2.01
Semi Annual Report 2.03
Failure Mode and Effect Analysis Report 2.03
Update Configuration Management Plan 2.06
Report Failure Mode and Effects Analysis 2.07

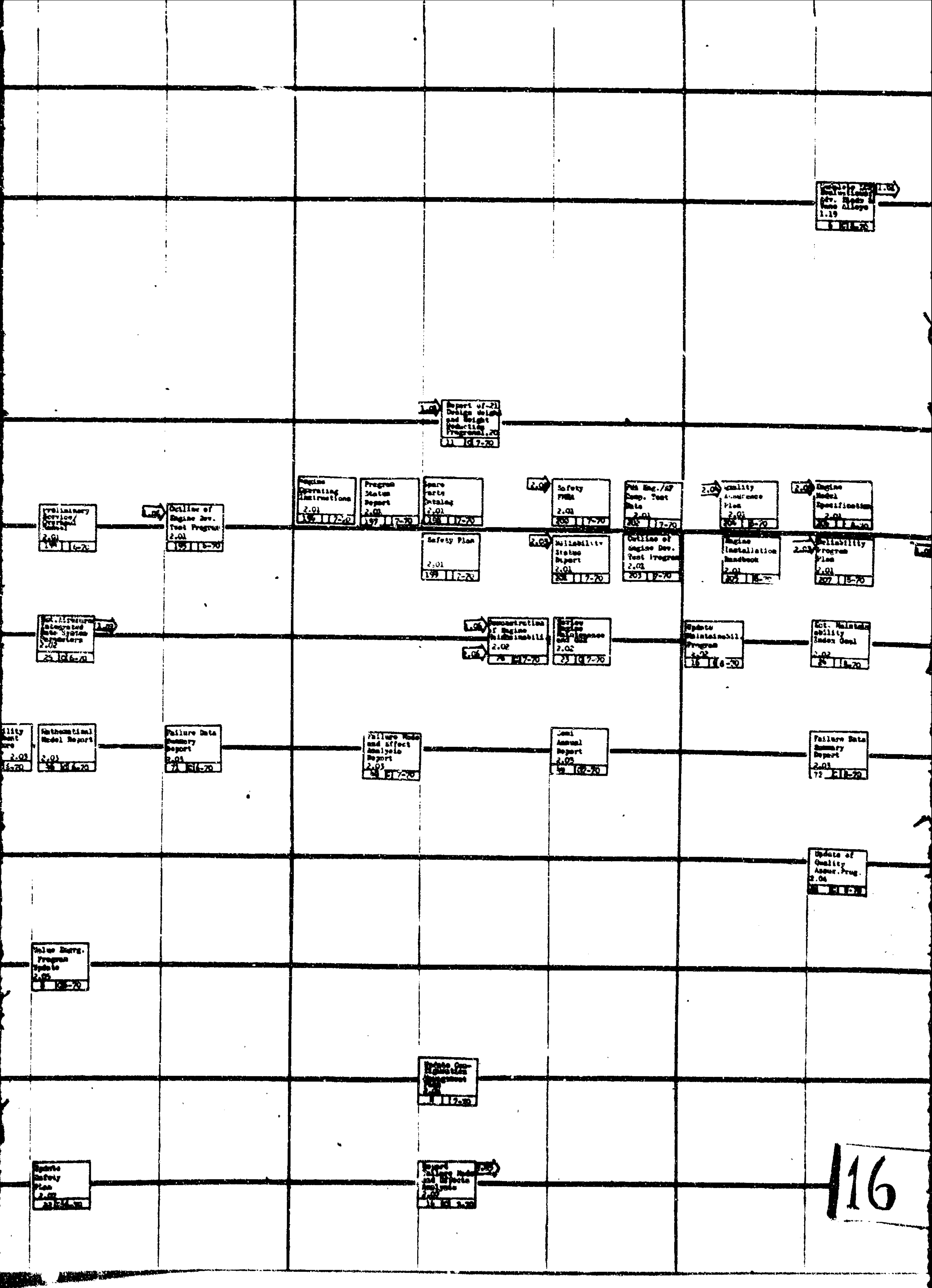


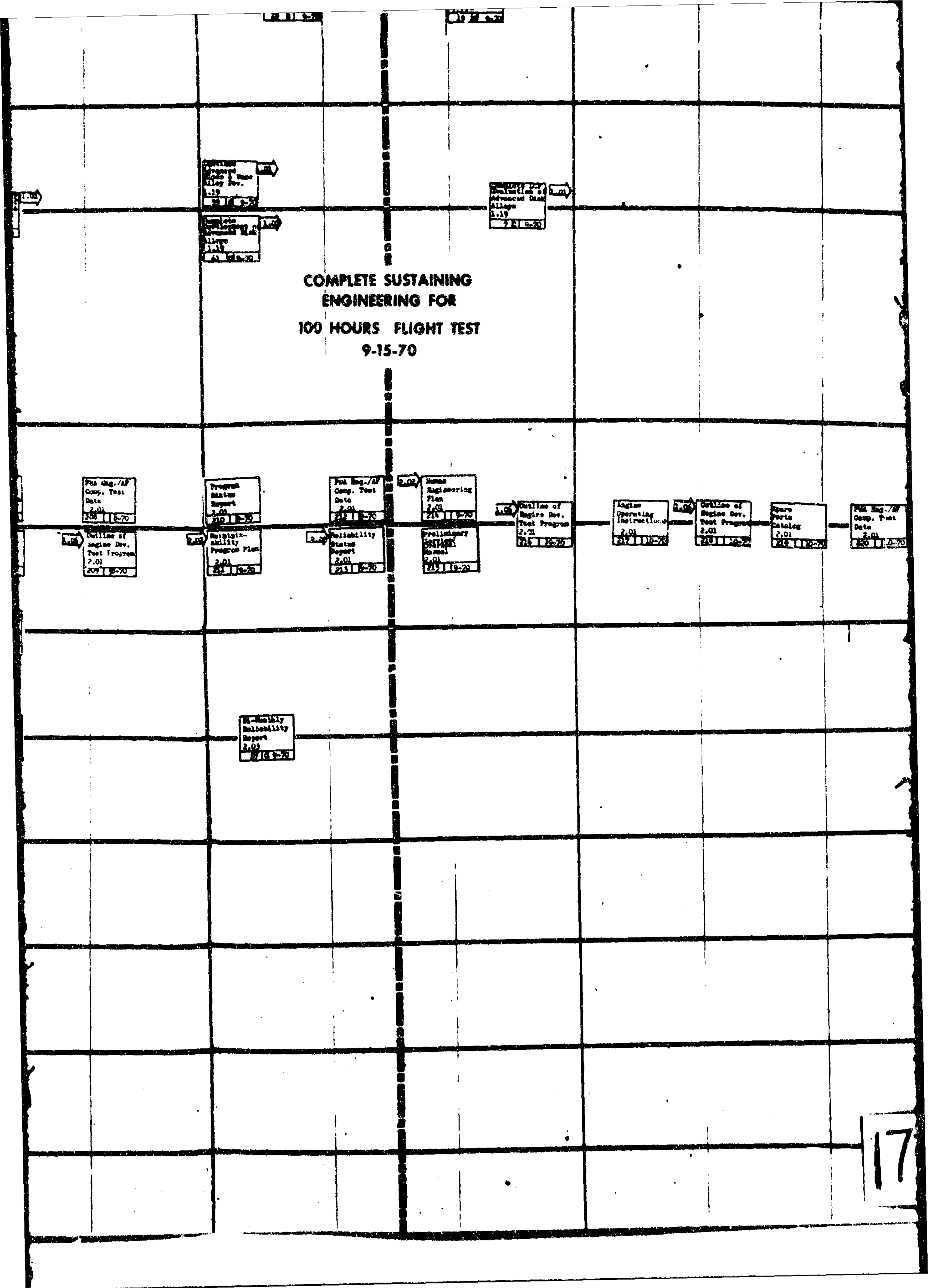
CONTINUE LUBRICATION SYS
CONTINUE FUELS TESTING IN
Quality Assurance Plan
2.01
2-70
Reliability Program Plan
2.01
172
2-70
Outline of Engine Dev. Test Program
2.01
173
2-70
Engine Installation Handbook
2.01
174
2-70
PWA Eng./AF Comp. Test Data
2.01
175
2-70
Safety Plan
2.01
176
2-70
Program Status Report
2.01
177
3-70
Human Engineering Plan
2.01
178
3-70
Reliability Status Report
2.01
179
3-70
Maintainability Program Plan
2.01
180
3-70
PWA Eng./AF Comp. Test Data
2.01
3-70
Preliminary Service/Overhaul Manual
2.01
Outline of Engine Dev. Test Program
2.01
3-70
Outline of Engine Dev. Test Program
2.01
4-70
Update Maintainabil Program
2.02
15
2-70
Failure Data Summary
2.03
2-70
Reliability Block Diagram
2.03
3-70
Bi-Monthly Reliability Report
2.03
35
3-70
Failure Data Summary Report
2.01
70
4-70
Update of Quality Assur. Prog.
2.04
27
2-70

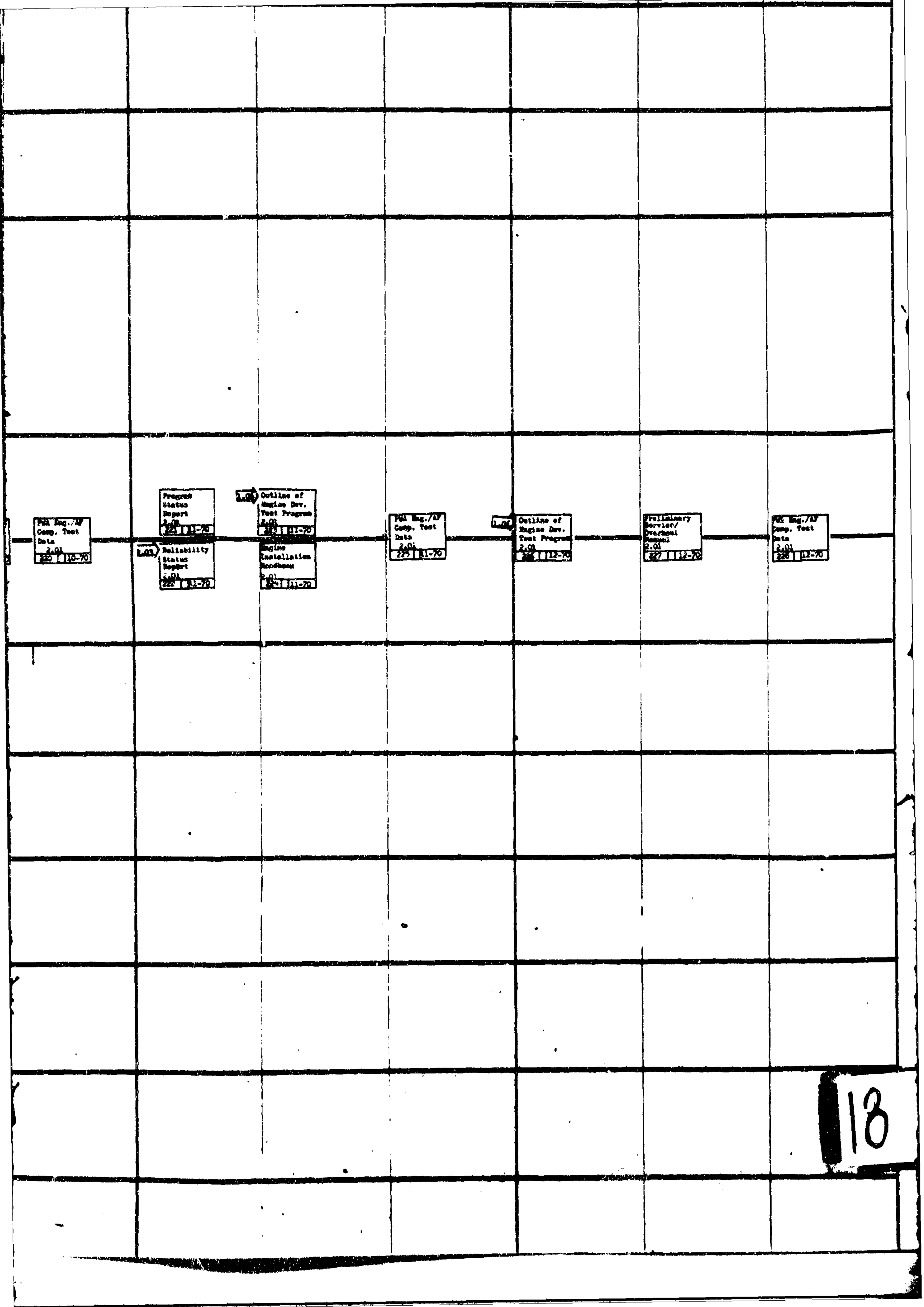
14



E FUELS TESTING IN SUPPORT OF 100 HOURS FLIGHT TEST
Engine Operating Instructions 2.01
Parts Catalog
Comp. Test Data 2.01
Engine Installation Handbook 2.01
Outline of Engine Dev. Test Program 2.01
Program Status Report 2.01
Reliability Status Report 2.01
Comp. Test Data 2.01
Preliminary 2.01
Engineering Program 2.02
Integrated Data System Parameters 2.03
Failure Mode and Effect Analysis 2.03
Reliability Apportionment Report 2.03
Bi-Monthly Reliability Report 2.03
Reliability Assessment Procedure Report 2.03
Mathematical Model Report 2.03
Value Engrg. Program Update
15


Safety Plan
2.01
199 7-70
Safety FMEA
2.01
200 7-70
Program Status Report
2.01
197 7-70
Outline of Engine Dev. Test Program
2.01
195 5-70
Mathematical Model Report
2.01
36 6-70
Failure Data Summary Report
2.01
71 6-70
Failure Mode and Effect Analysis Report
2.03
Semi Annual Report
2.05
Failure Data Summary Report
2.01
Value Engrg. Program Update
2.05


COMPLETE SUSTAINING ENGINEERING FOR 100 HOURS FLIGHT TEST 9-15-70
Comp. Test
Data
2.01
Outline of
Engine Dev.
Test Program
2.01
Program
Status
Report
Progress Plan
Reliability
Status
Report
Engineering
Plan
Manual
Operating
Instructions
Spare
Parts
Catalog
Bi-Monthly
Reliability
Report
17



PWA Eng./AF
Comp. Test
Data
2.01
220
10-70
Program
Status
Report
221
11-70
2.03
Reliability
Status
Report
2.01
222
11-70
1.04
Outline of
Engine Dev.
Test Program
2.01
11-70
Engine
Installation
Handbook
2.01
11-70
PWA Eng./AF
Comp. Test
Data
2.01
225
11-70
1.04
Outline of
Engine Dev.
Test Program
2.01
12-70
Preliminary
Service/
Overhaul
Manual
2.01
227
12-70
Eng./AF
Comp. Test
Data
2.01
228
12-70

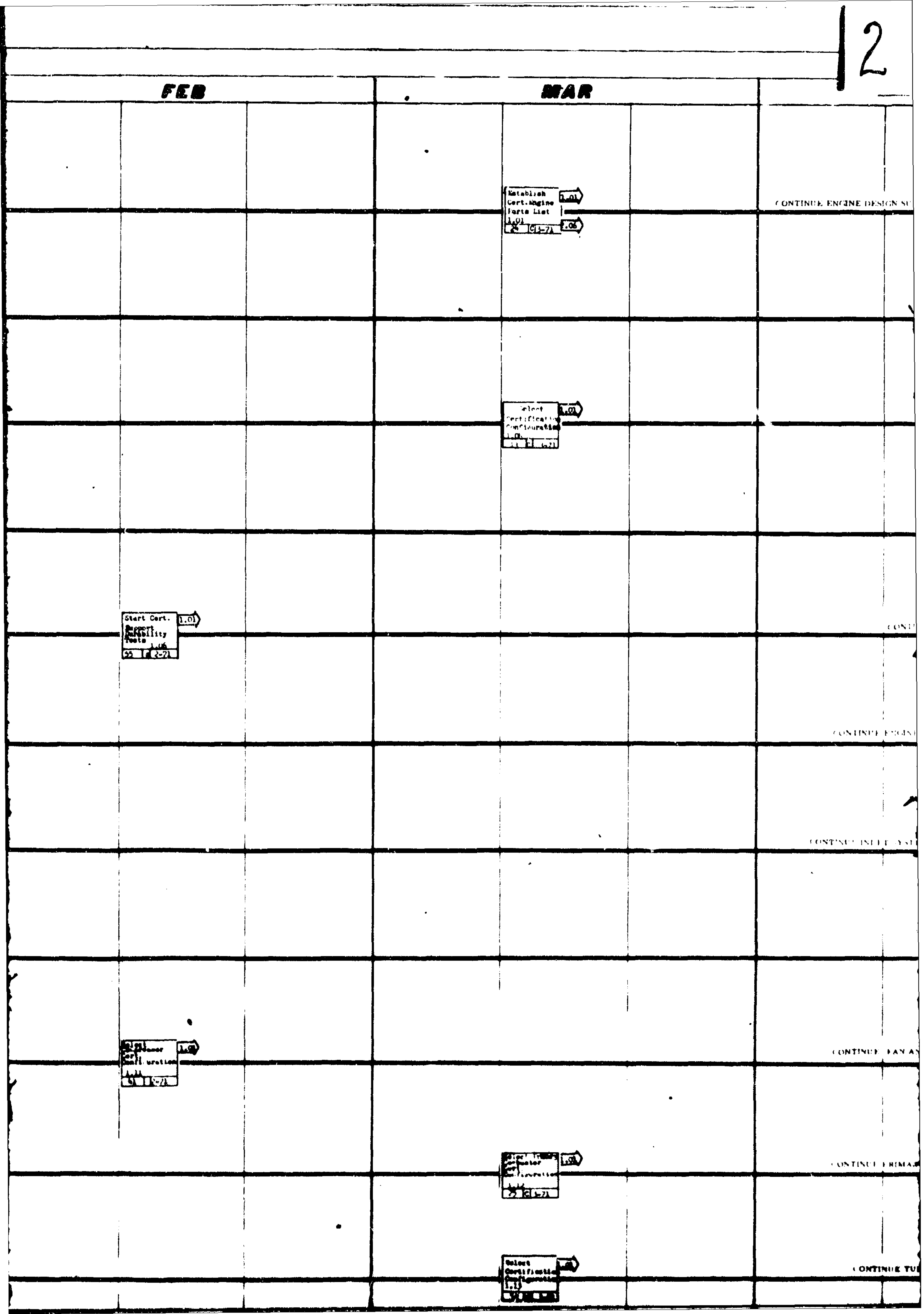
PHASE III
WORK BREAKDOWN
JTF17

1971

TEST PLANNING AND INTEGRATION

1

PHASE III WORK BREAKDOWN JTF17		JAN			
ENGINE DESIGN	1.01				
FABRICATION AND ASSEMBLY	1.02				
ENGINE INSTRUMENTATION	1.04				
TEST EQUIPMENT FACILITES	1.05 2.11				
ENGINE TEST - GROUND	1.06				
ENGINE PERFORMANCE	1.07				
INLET SYSTEM COMPATIBILITY	1.08				
NOISE	1.09				
FAN AND COMPRESSOR	1.11		Select Fan Certification Configuration 1.11 1-71		
PRIMARY COMBUSTOR	1.12				
TURBINE	1.13				


12
FEB
MAR
Establish Cert. Engine Parts List 1.01
1.01
.06
C 3-71
CONTINUE ENGINE DESIGN SU
Select Certification Configuration 1.0
1.01
Start Cert. Support Reliability Tests 1.06
1.01
55
2-71
CONT
CONTINUE ENGIN
CONTINUE INLET SYST
Select Compressor Cert. Configuration 1.11
1.0
CONTINUE FAN A
Select Primary Combustor Cert. Configuration
1.0
3-71
CONTINUE PRIMAR
Select Certification Configuration 1.13
1.0
CONTINUE TU

TEST PLANNI

13

APR			MAY				

TINUE ENGINE DESIGN SUPPORT FOR ENGINE CERTIFICATION

Complete Fin
Procurement
for 15th
Development
Engine

CONTINUE ENGINE TESTS

CONTINUE ENGINE PERFORMANCE EVALUATIONS

CONTINUE INLET SYSTEM COMPATIBILITY TESTS

CONTINUE FAN AND COMPRESSOR TESTS

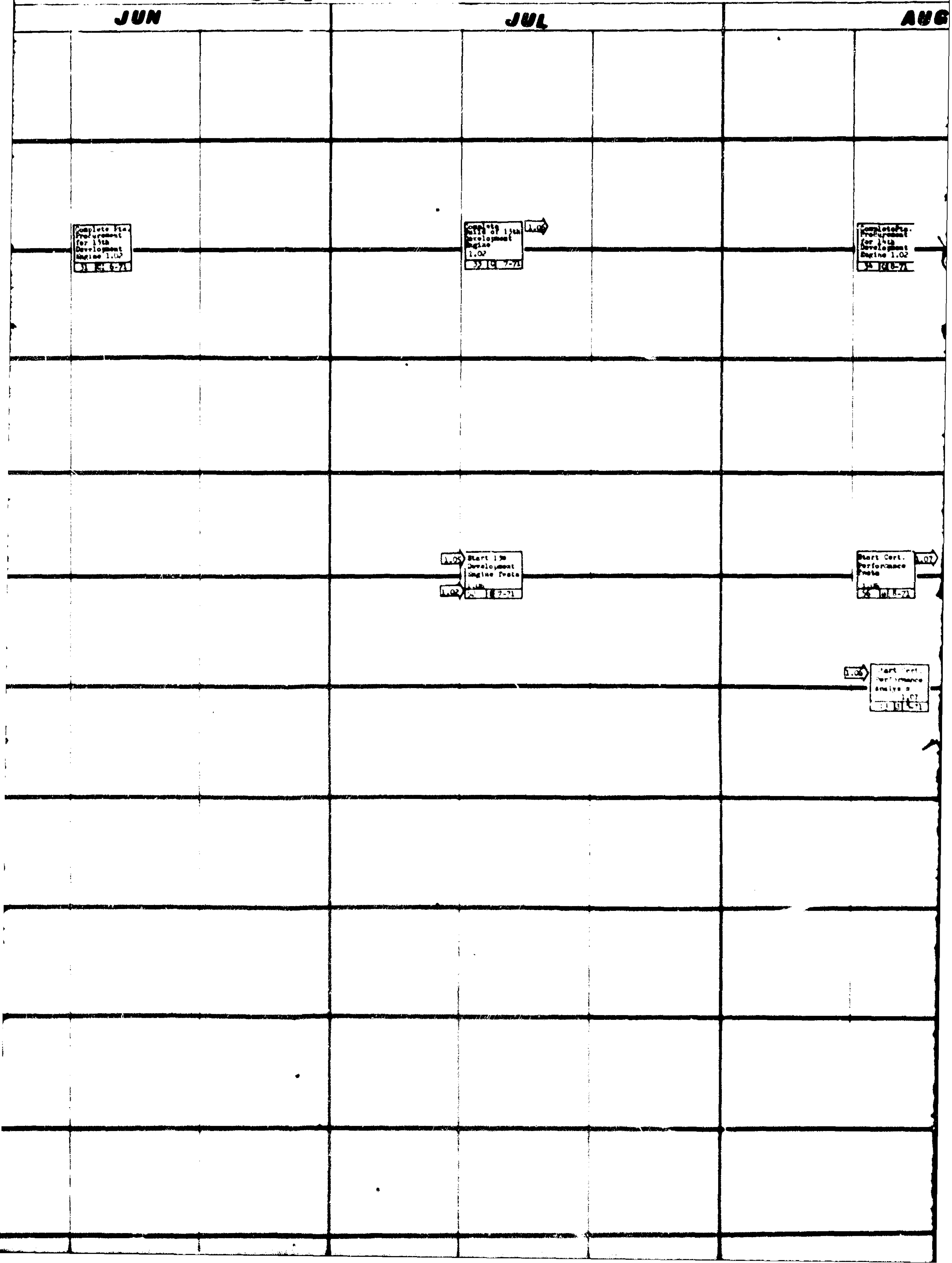
CONTINUE PRIMARY COMBUSTOR TESTS

CONTINUE TURBINE TESTS

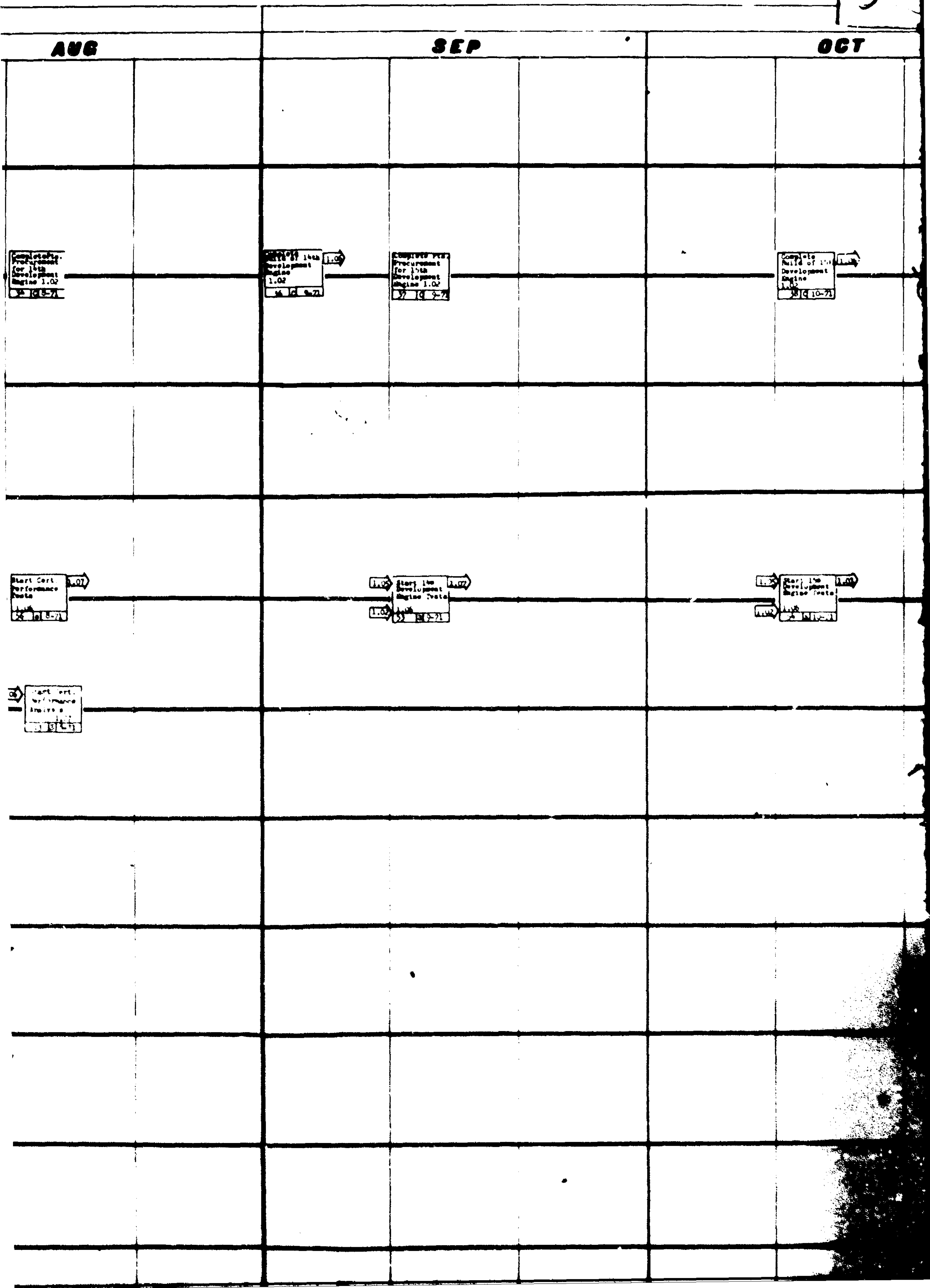
ING AND INTEGRATION

4

1971

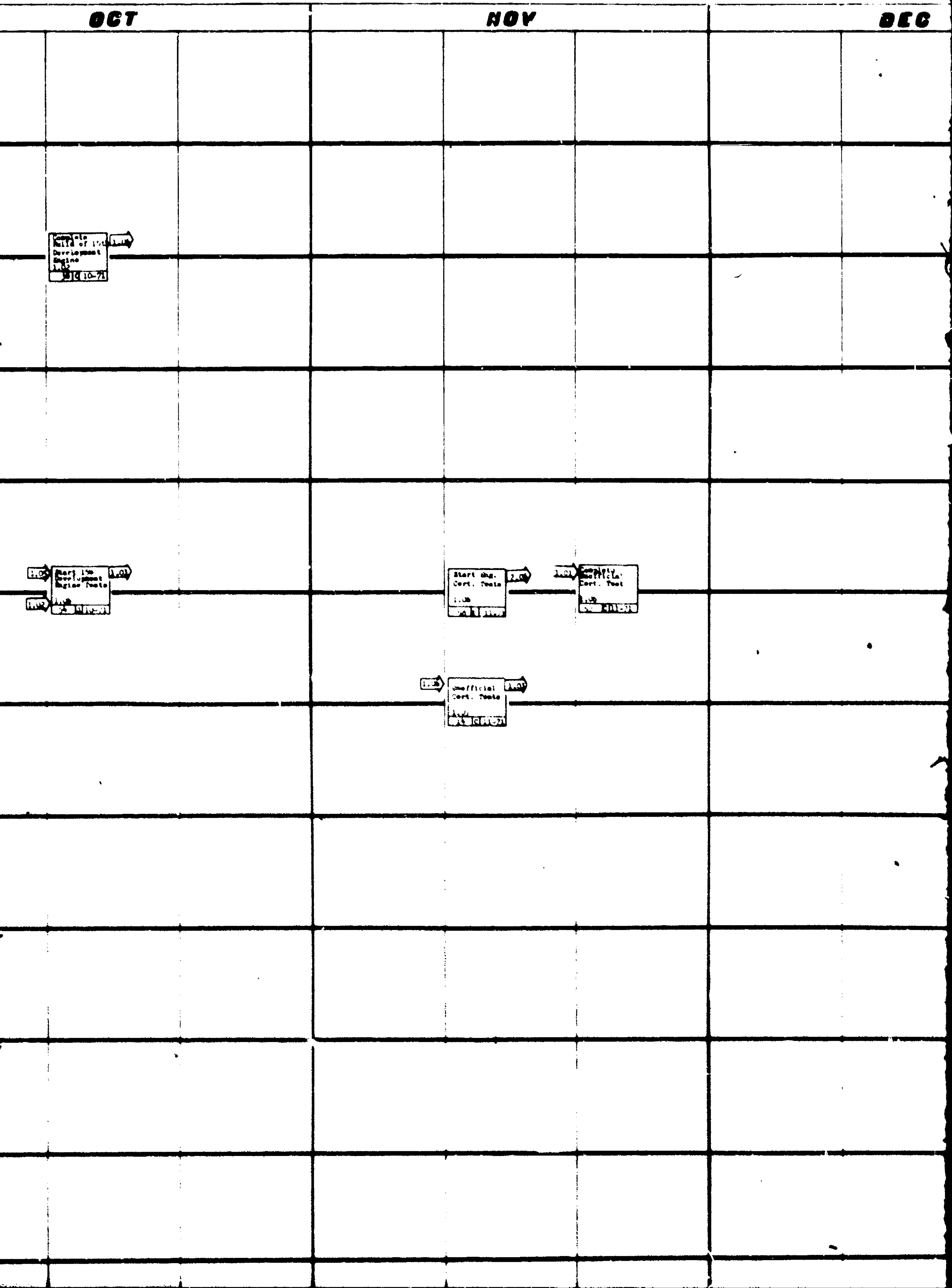


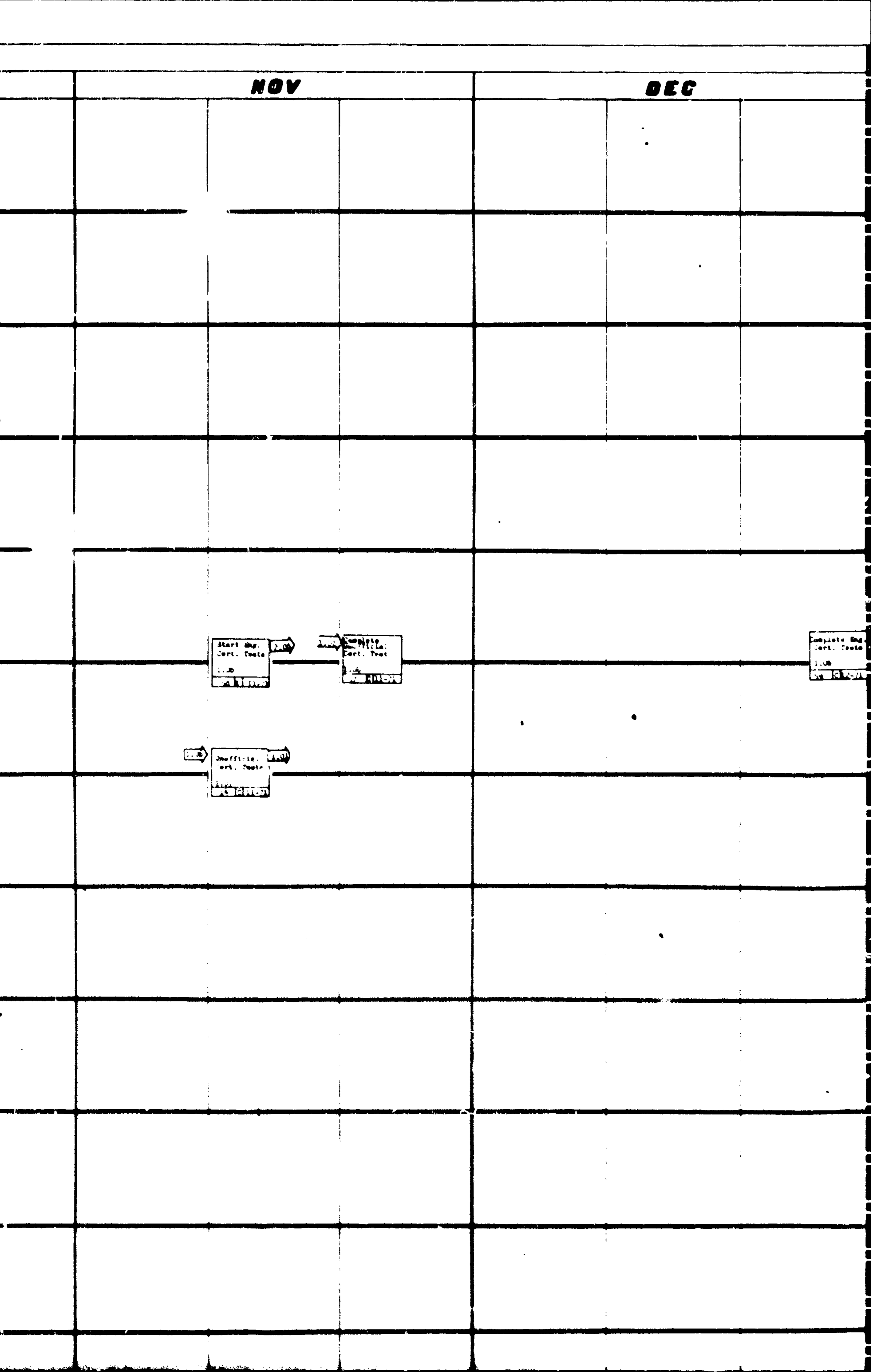
5



AUG
SEP
OCT
Procurement
for 15th
Development
Engine 1.02
1.02
Development
Engine 1.02
5-71
9-71
Complete
Development
Engine
10-71
Start Cert.
Performance
Tests
1.07
Development
1.05

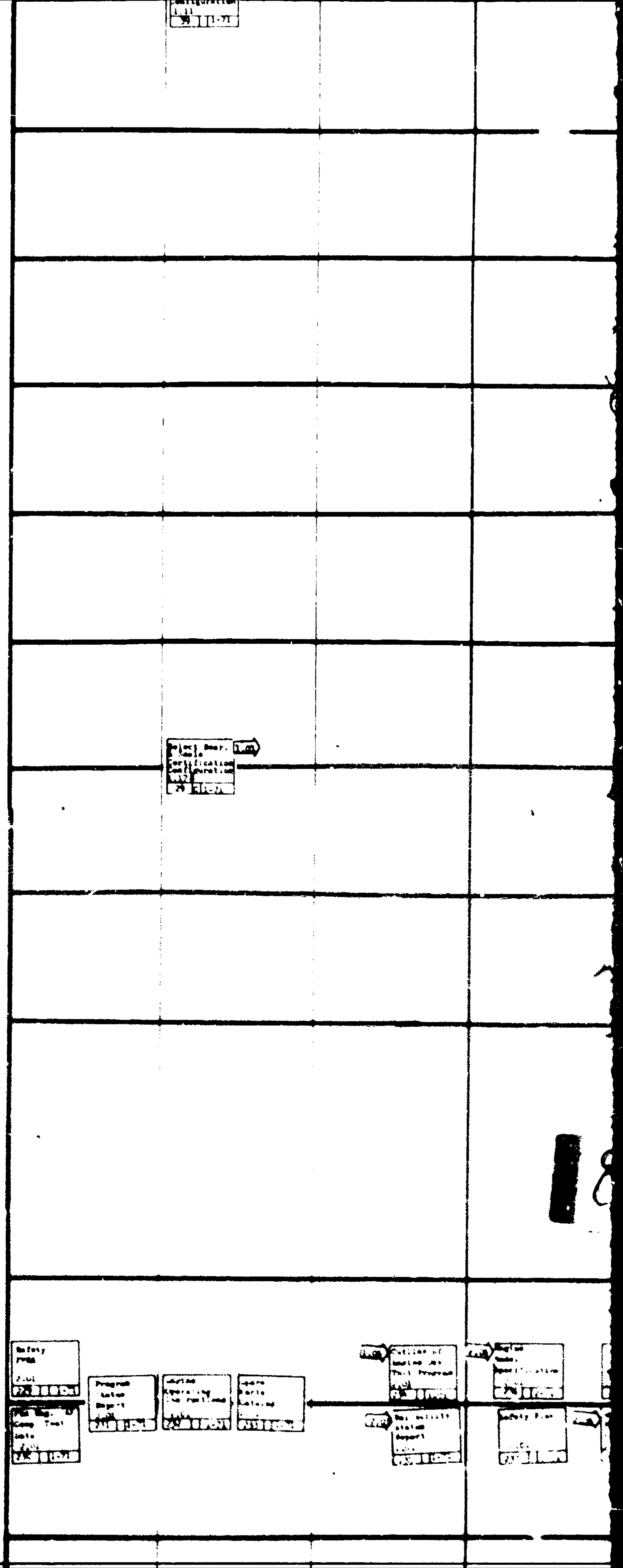
6

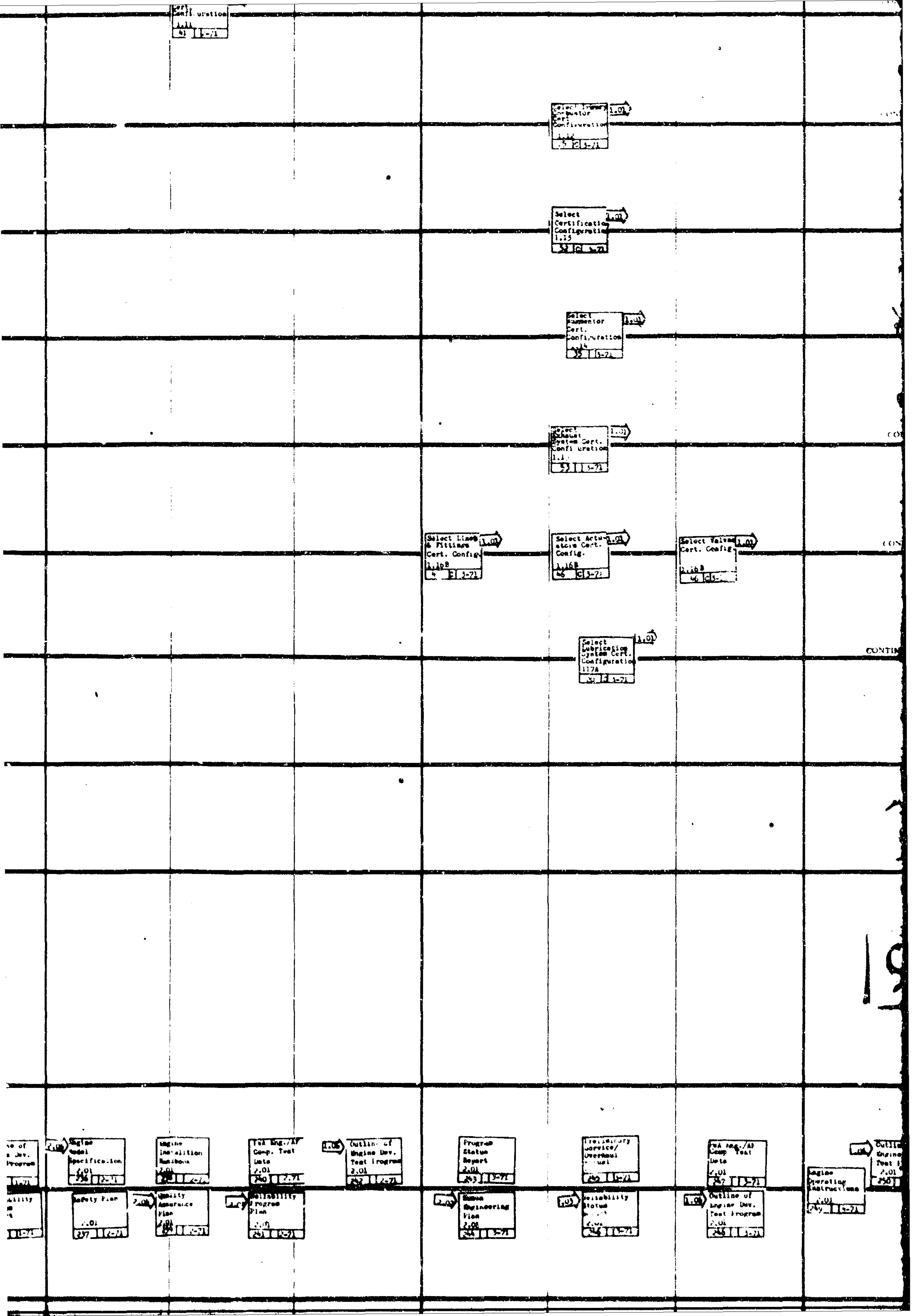

OCT
NOV
DEC
Complete
Development
Engine
10-71
Start Eng.
Cert. Tests
Cert. Test
Unofficial
Cert. Tests



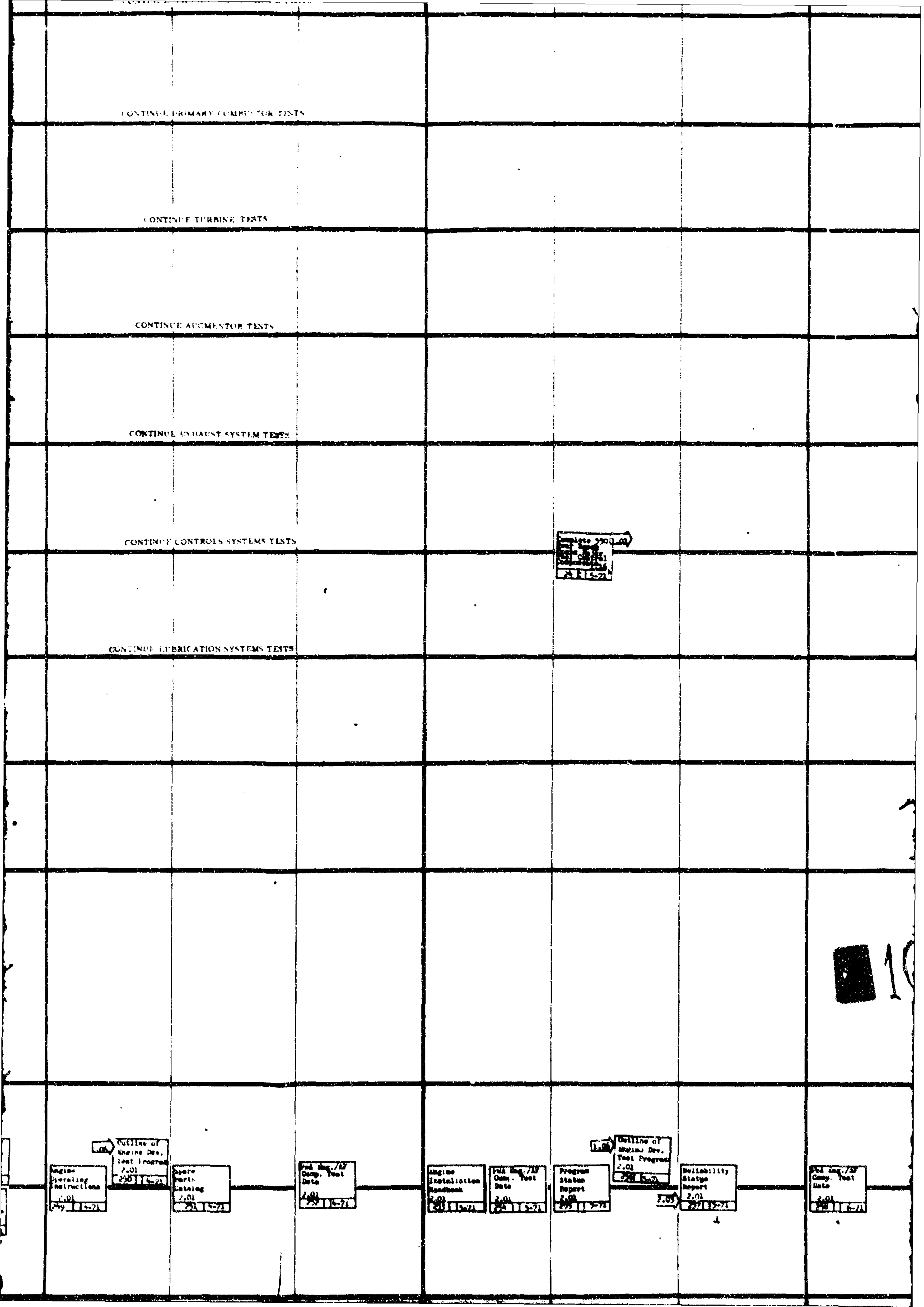
7

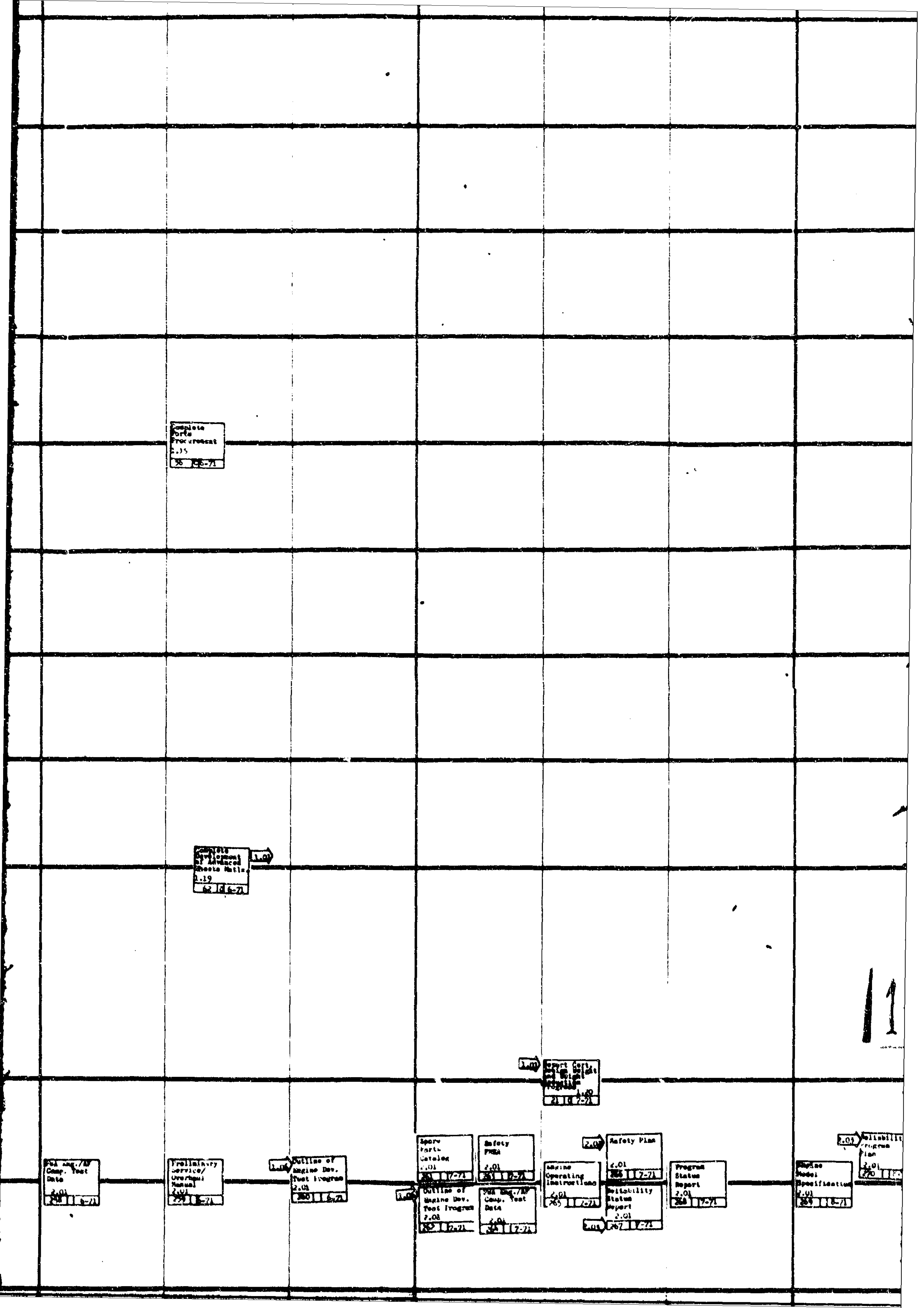
PRIMARY COMBUSTOR	1.12
TURBINE	1.13
AUGMENTOR	1.14
EXHAUST SYSTEM	1.15
CONTROLS AND ACCESSORIES	1.16
LUBRICANTS LUBRICATION SYSTEM BEARINGS SEAL AND GEARS	1.17
FUELS	1.18
MANUFACTURING TECHNIQUES AND MATERIALS	1.19
WEIGHT CONTROL AND STATUS	1.20
COORDINATION	2.01
MAINTAINABILITY HUMAN ENGINEERING	2.02



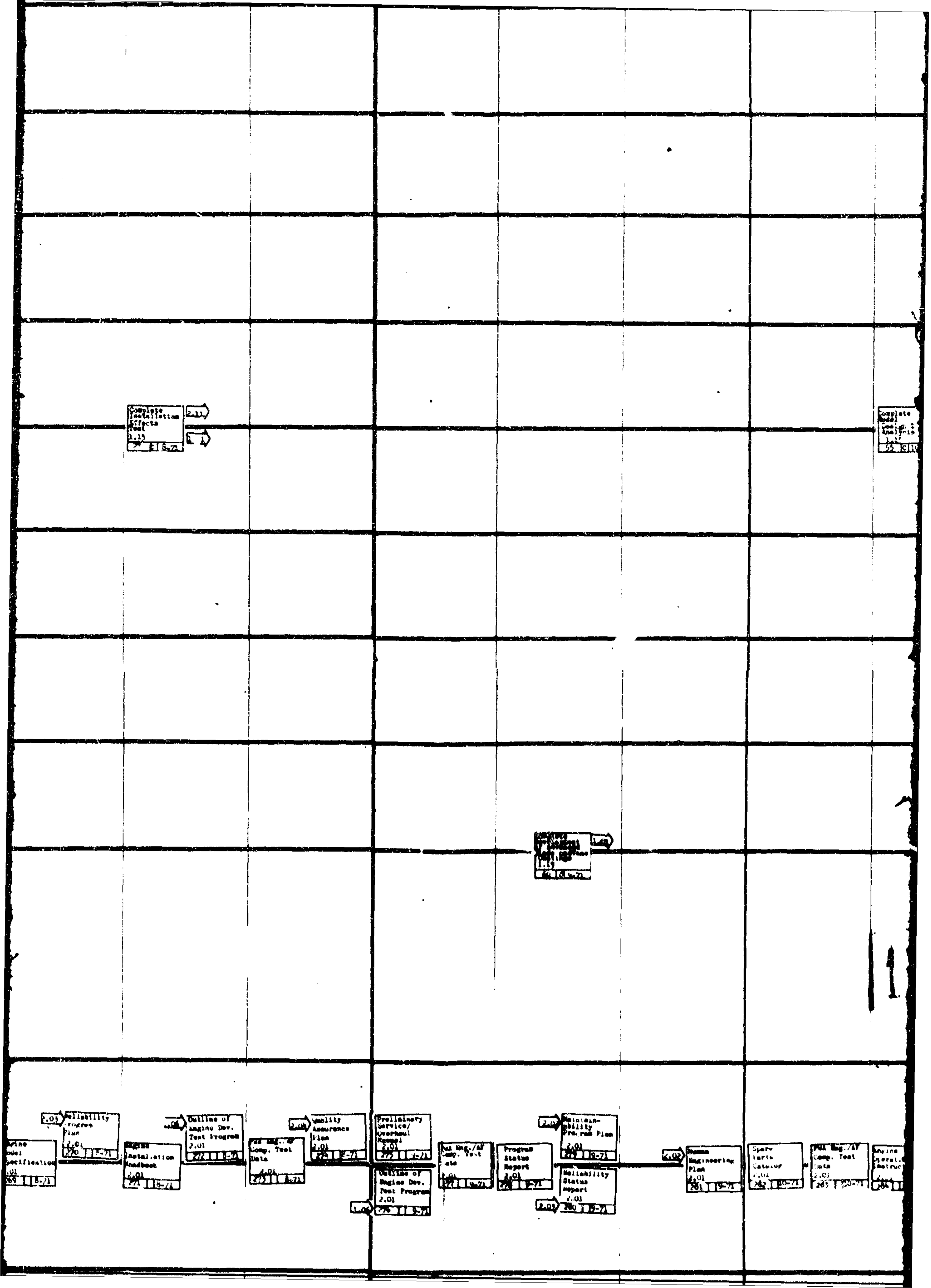


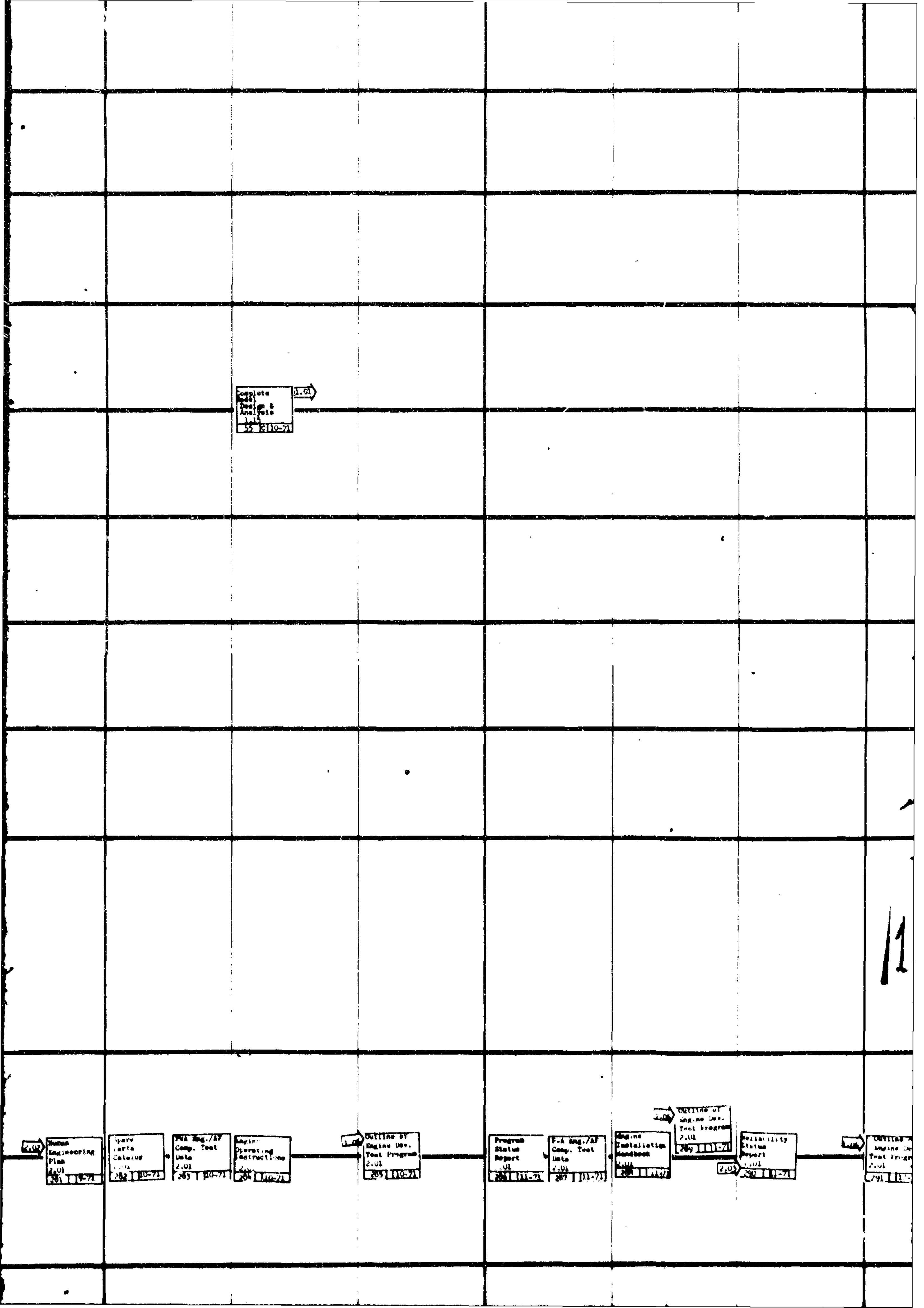
Select Certification Configuration 1.15
Select Exhaust System Cert. Configuration
Select Lines & Fittings Cert. Config.
Select Actuators Cert. Config.
Select Valves Cert. Config.
Select Lubrication System Cert. Configuration 1.17A
Engine Model Specification 2.01
Safety Plan 2.01
Engine Installation Handbook 2.01
Quality Assurance Plan 2.01
Reliability Program Plan
Outline of Engine Dev. Test Program 2.01
Program Status Report 2.01
Human Engineering Plan
Preliminary Service/Overhaul Manual
Reliability Status
Outline of Engine Dev. Test Program
Engine Operating Instructions
CONTIN


CONTINUE PRIMARY COMBUSTOR TESTS
CONTINUE TURBINE TESTS
CONTINUE AUGMENTOR TESTS
CONTINUE EXHAUST SYSTEM TESTS
CONTINUE CONTROLS SYSTEMS TESTS
CONTINUE LUBRICATION SYSTEMS TESTS
Engine Operating Instructions
2.01
Outline of Engine Dev. Test Program
2.01
290
Spare Parts Catalog
2.01
Engine Installation Handbook
2.01
Program Status Report
2.01
Outline of Engine Dev. Test Program
2.01
Reliability Status Report
2.01
2.05
297
2.01
6-71

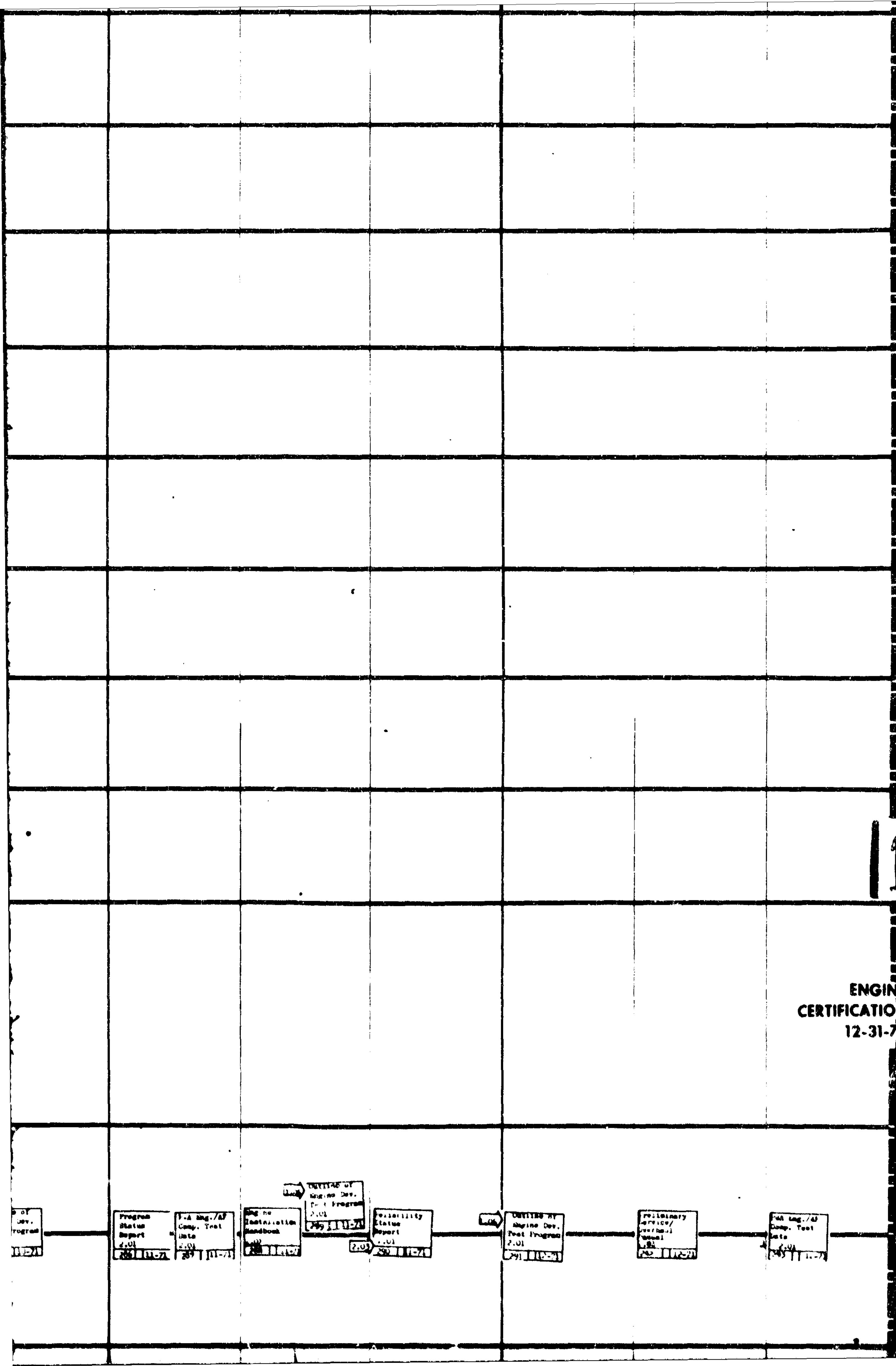


Complete
Parts
Procurement
Complete
Development
of Advanced
Sheets Matls.
1.19
6-71
Comp. Test
Data
2.01
6-71
Preliminary
Service/
Overhaul
Manual
Outline of
Engine Dev.
Test Program
2.01
Spare
Parts
Catalog
7-71
Safety
FMEA
2.01
Outline of
Engine Dev.
Test Program
7-71
Comp. Test
Data
7-71
Engine
Operating
Instructions
2.01
7-71
Safety Plan
2.01
7-71
Reliability
Status
Report
2.01
267
7-71
Program
Status
Report
2.01
7-71
Engine
Model
Specification
2.01
269
8-71
Program
Plan
2.01
270
11


Complete Installation Effects Test
1.15
Reliability Program Plan
2.01
Outline of Engine Dev. Test Program
2.01
Comp. Test Data
Quality Assurance Plan
2.01
Preliminary Service/ Overhaul Manual
2.01
Outline of Engine Dev. Test Program
2.01
Program Status Report
2.01
Maintainability Program Plan
2.01
Reliability Status Report
2.01
Human Engineering Plan
2.01
Comp. Test Data



Complete
Model
Design &
Analysis
1.15
55
10-71
1.01
2.02
Human
Engineering
Plan
2.01
201
9-71
Spare
Parts
Catalog
202
10-71
PWA Eng./AF
Comp. Test
Data
2.01
203
10-71
Engine
Operating
Instructions
204
10-71
1.06
Outline of
Engine Dev.
Test Program
2.01
205
10-71
Program
Status
Report
206
11-71
F-A Eng./AF
Comp. Test
Data
2.01
207
11-71
Engine
Installation
Handbook
2.01
208
Outline of
Engine Dev.
Test Program
2.01
209
11-71
Reliability
Status
Report
2.03
Outline of
Engine Dev.
Test Program
2.01
11



14

ENGINE
CERTIFICATION
12-31-71

FUELS 1.18

MANUFACTURING TECHNIQUES AND MATERIALS 1.19

WEIGHT CONTROL AND STATUS 1.20

COORDINATION 2.01

MAINTAINABILITY HUMAN ENGINEERING 2.02

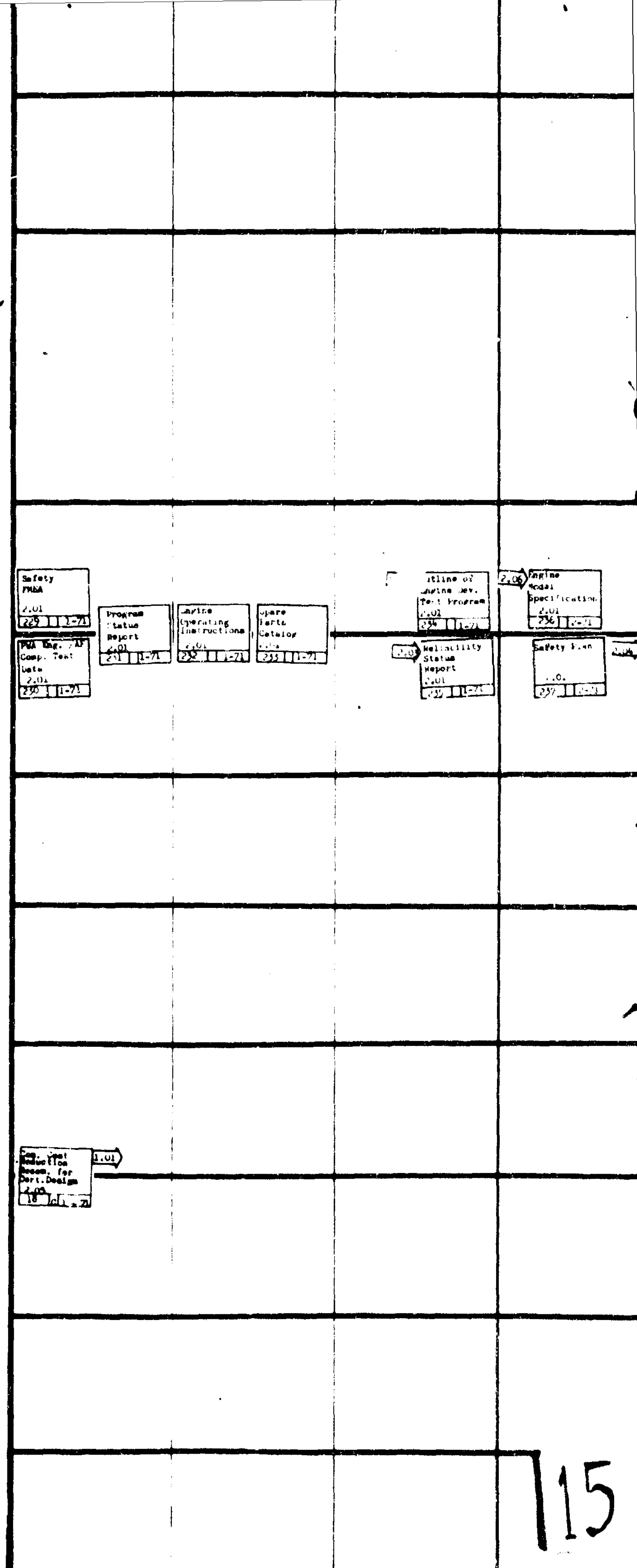
RELIABILITY 2.03

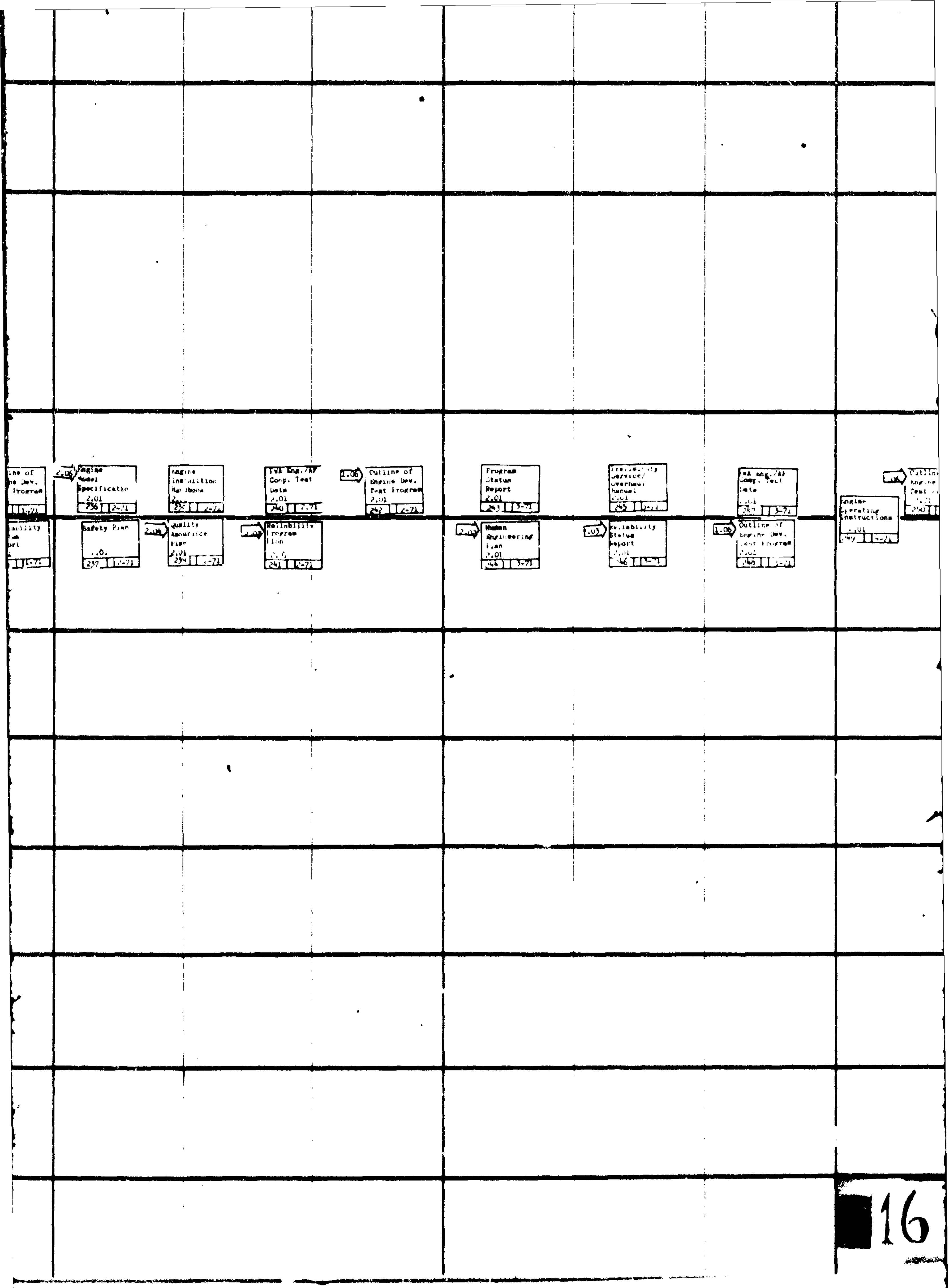
QUALITY ASSURANCE 2.04

VALUE ENGINEERING 2.05

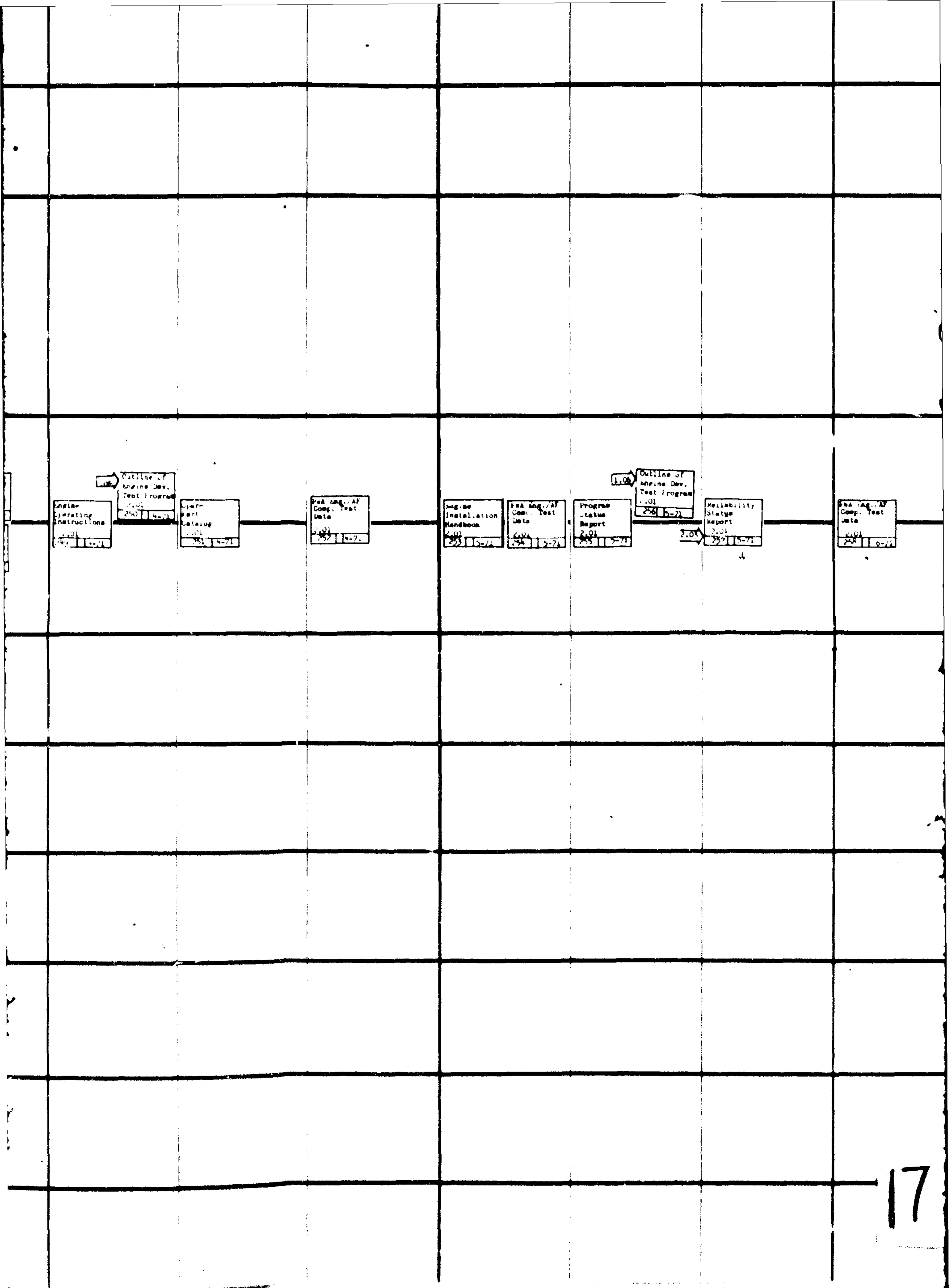
CONFIGURATION MANAGEMENT 2.06

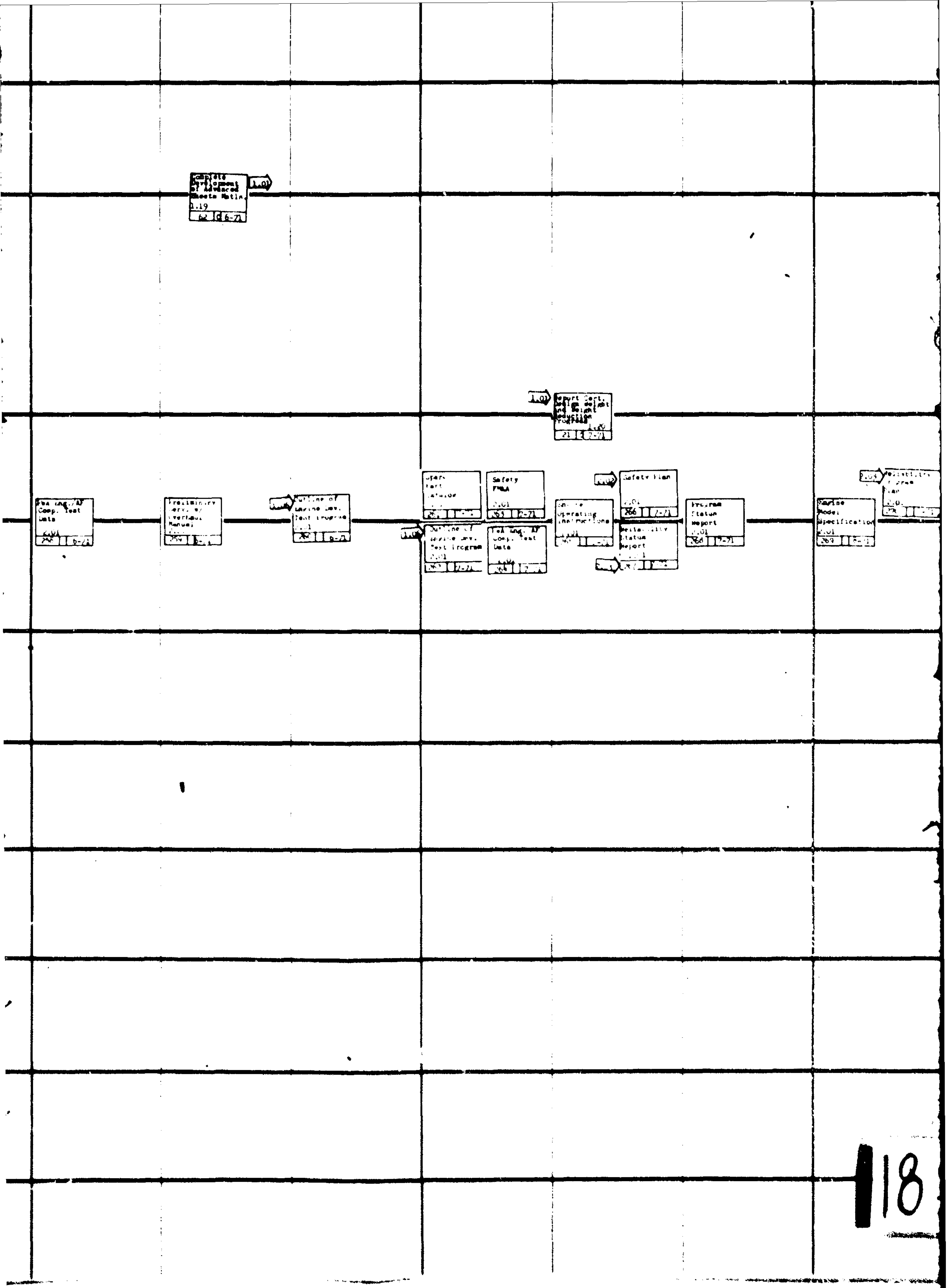
SAFETY 2.07

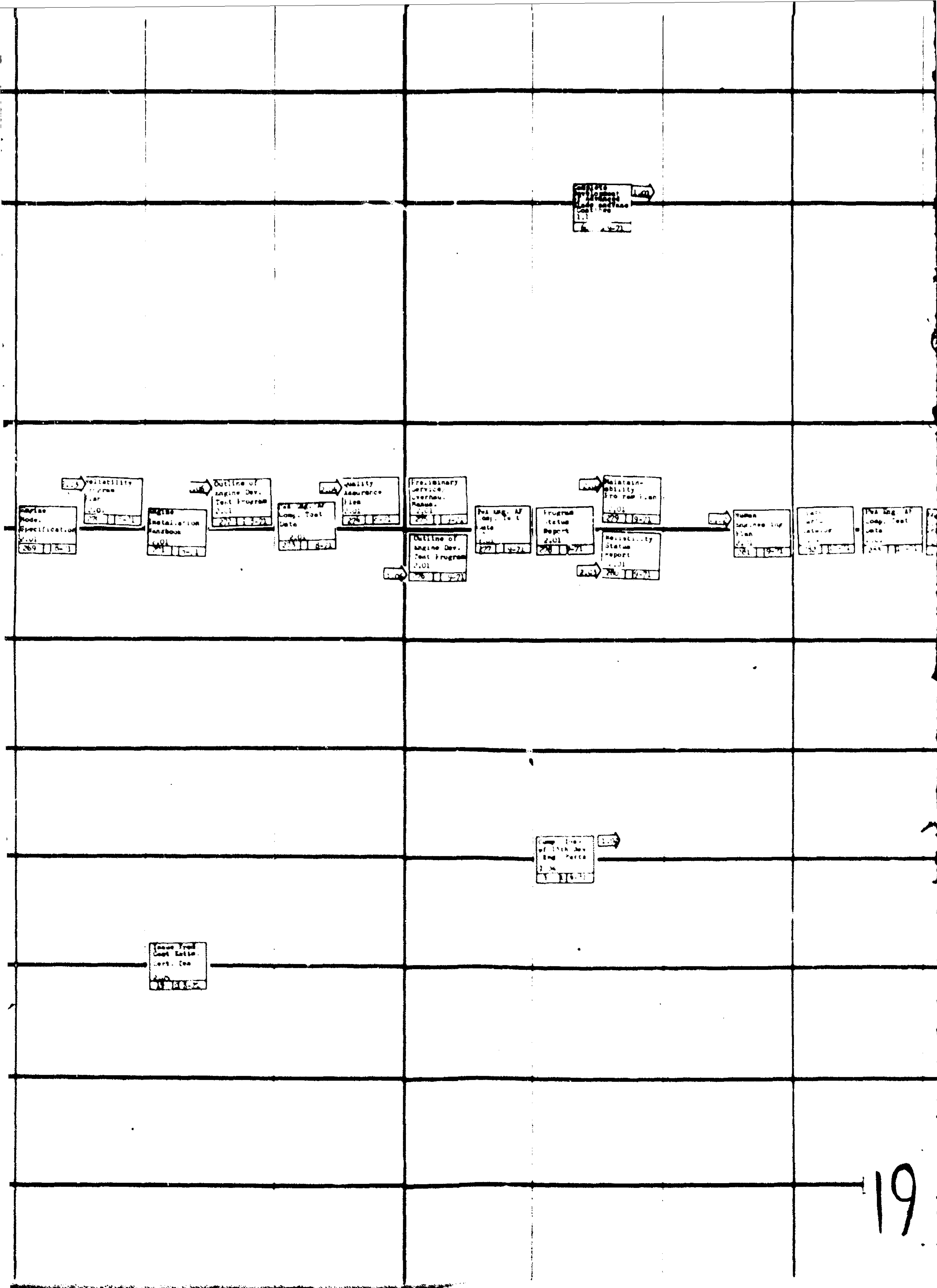




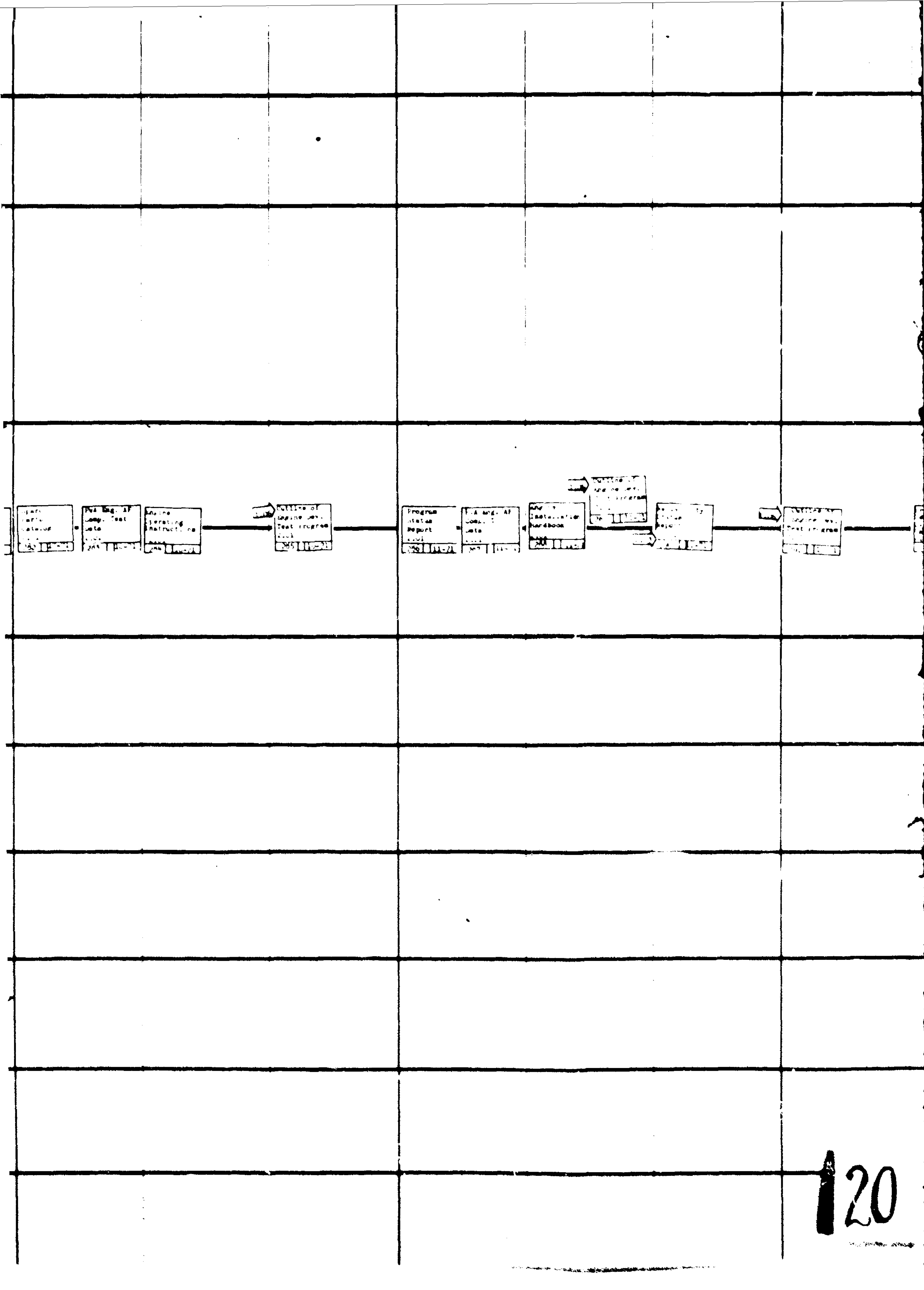
Engine
Model
Specification
2.01
236
2-71
Engine
Installation
Handbook
2-71
TWA Eng./AF
Comp. Test
Data
2.01
240
2-71
Outline of
Engine Dev.
Test Program
2.01
242
2-71
Program
Status
Report
2.01
3-71
Service/
Overhaul
Manual
3-71
Comp. Test
Data
3-71
Engine
Operating
Instructions
250
Safety Plan
237
2-71
Quality
Assurance
Plan
2.01
2-71
Reliability
Program
Plan
241
2-71
Engineering
Plan
2.01
3-71
Reliability
Status
Report
Outline of
Engine Dev.
Test Program
2.06
1.06
1.03


Outline of Engine Dev. Test Program
Spare Part Catalog
Comp. Test Data
Installation Handbook
2.01
Program Status Report
2.01
5-71
1.06
Outline of Engine Dev. Test Program
Reliability Status Report
2.01
Comp. Test Data

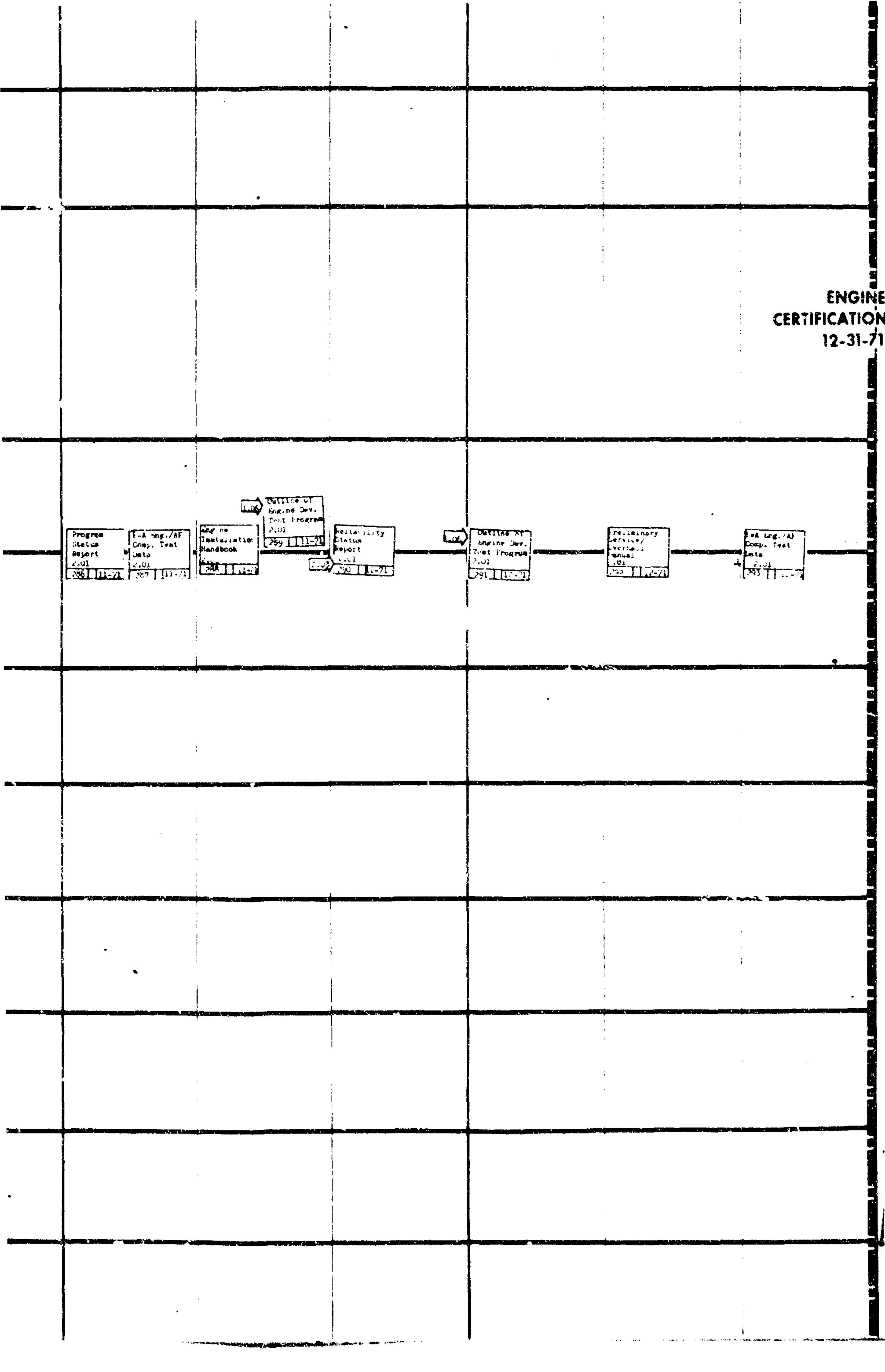

Complete Development of Advanced Sheets Matls.
1.19
62
6-71
1.01
1.01
Report Cert. Design Weight and Weight Reduction Program
1.20
21
7-71
Comp. Test Data
Manual
Outline of Engine Dev. Test Program
6-71
Safety FMEA
2.01
7-71
Operating Instructions
Safety Plan
2.01
266
7-71
Status Report
Program Status Report
2.01
7-71
Engine Model Specification
2.01
269
Comp. Test Data
Test Program
7-71


Engine Mode. Specification 2.01
Reliability Program Plan
Engine Installation Handbook 2.01
Outline of Engine Dev. Test Program 2.01
Quality Assurance Plan 2.01
Preliminary Service Overhaul Manual 2.01
Outline of Engine Dev. Test Program 2.01
Program Status Report 2.01
Maintainability Program Plan 2.01
Reliability Status Report 2.01
Human Engineering Plan

19



Catalog
Comp. Test
Data
Engine
Operating
Instructions
Outline of
Engine Dev.
Test Program
Program
Status
Report
Data
Installation
Handbook
Outline of
Engine Dev.
Test Program


ENGINE CERTIFICATION 12-31-71
Progress Status Report 2.01
286
11-71
Comp. Test Data 2.01
287
11-71
Installation Handbook
Outline of Engine Dev. Test Program 2.01
259
11-71
1.06
Status Report
Outline of Engine Dev. Test Program
291
12-71
Preliminary Service/ Manual
Comp. Test Data